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NDARC
NASA Design and Analysis of Rotorcraft

Input and Data Structures

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January 2022

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Contents

Chapter 1

Data Structures and Input

1–1 Overview

The NDARC code performs design and analysis tasks. The design task involves sizing the rotorcraft to satisfy specified design conditions and missions. The analysis tasks can include off-design mission performance analysis, flight performance calculation for point operating conditions, and generation of subsystem or component performance maps. Figure 1-1 illustrates the tasks. The principal tasks (sizing, mission analysis, flight performance analysis) are shown in the figure as boxes with heavy borders. Heavy arrows show control of subordinate tasks.

The aircraft description (figure 1-1) consists of all the information, input and derived, that defines the aircraft. The aircraft consists of a set of components, including fuselage, rotors, wings, tails, and propulsion. This information can be the result of the sizing task; can come entirely from input, for a fixed model; or can come from the sizing task in a previous case or previous job. The aircraft description information is available to all tasks and all solutions (indicated by light arrows).

The sizing task determines the dimensions, power, and weight of a rotorcraft that can perform a specified set of design conditions and missions. The aircraft size is characterized by parameters such as design gross weight, weight empty, rotor radius, and engine power available. The relations between dimensions, power, and weight generally require an iterative solution. From the design flight conditions and missions, the task can determine the total engine power or the rotor radius (or both power and radius can be fixed), as well as the design gross weight, maximum takeoff weight, drive system torque limit, and fuel tank capacity. For each propulsion group, the engine power or the rotor radius can be sized.

Missions are defined for the sizing task, and for the mission performance analysis. A mission consists of a number of mission segments, for which time, distance, and fuel burn are evaluated. For the sizing task, certain missions are designated to be used for design gross weight calculations; for transmission sizing; and for fuel tank sizing. The mission parameters include mission takeoff gross weight and useful load. For specified takeoff fuel weight with adjustable segments, the mission time or distance is adjusted so the fuel required for the mission (burned plus reserve) equals the takeoff fuel weight. The mission iteration is on fuel weight or energy.

Flight conditions are specified for the sizing task, and for the flight performance analysis. For the sizing task, certain flight conditions are designated to be used for design gross weight calculations; for transmission sizing; for maximum takeoff weight calculations; and for antitorque or auxiliary thrust rotor sizing. The flight condition parameters include gross weight and useful load.

For flight conditions and mission takeoff, the gross weight can be maximized, such that the power required equals the power available.

A flight state is defined for each mission segment and each flight condition. The aircraft performance can be analyzed for the specified state, or a maximum effort performance can be identified. The maximum effort is specified in terms of a quantity such as best endurance or best range, and a variable such as speed, rate of climb, or altitude. The aircraft must be trimmed, by solving for the controls and motion that produce equilibrium in the specified flight state. Different trim solution definitions are required for various flight states. Evaluating the rotor hub forces may require solution of the blade flap equations of motion.

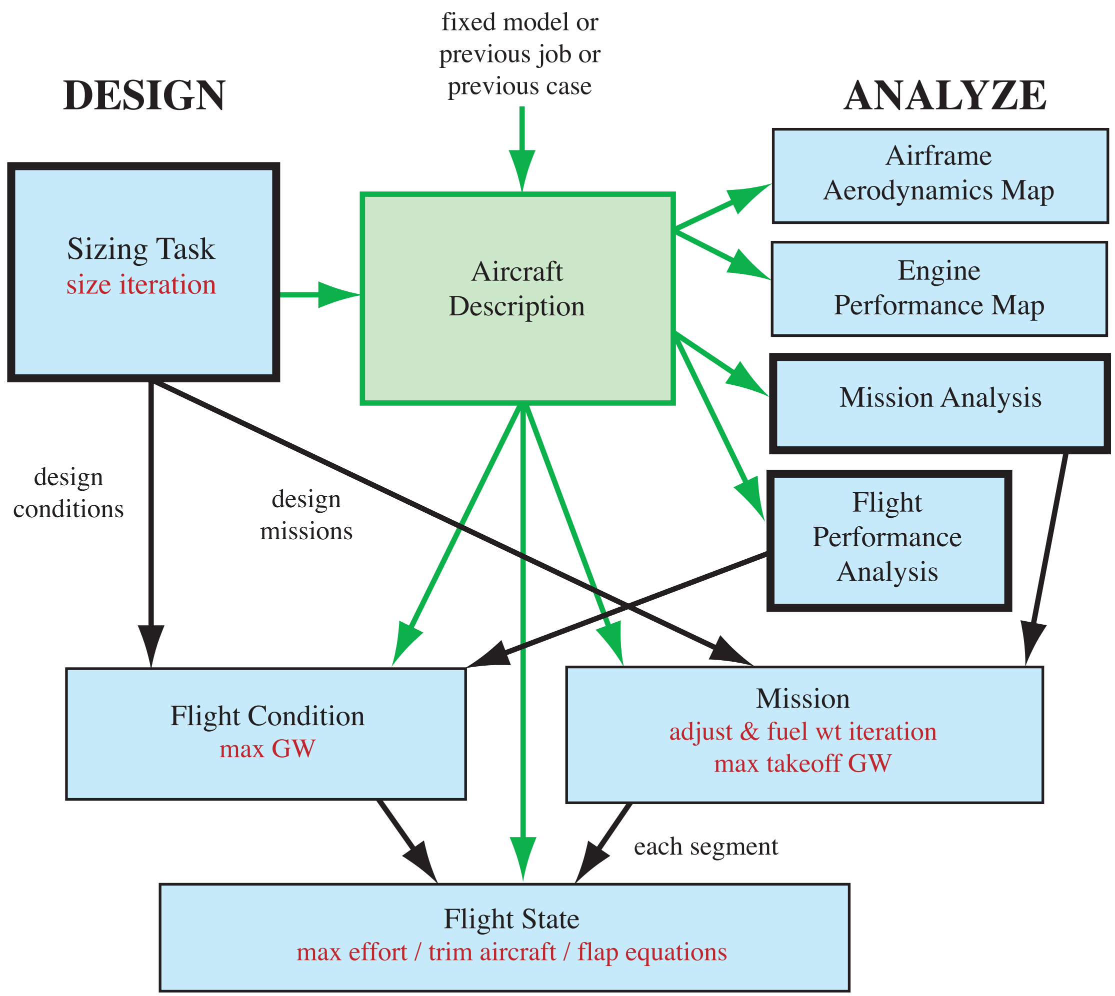

Figure 1-1 Outline of NDARC tasks.

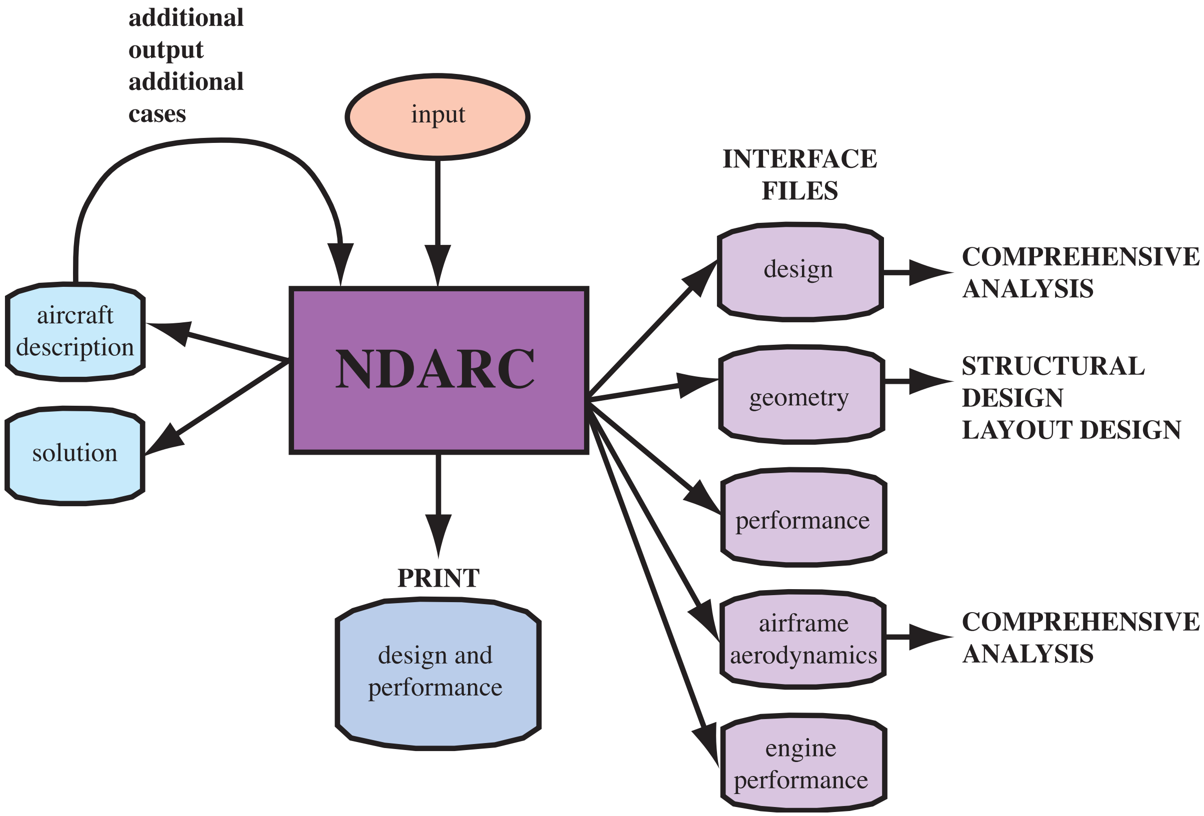

Figure 1-2 NDARC Interfaces.

```
&JOB INIT_input=0,INIT_data=0,&END
&DEFN action='ident',created='time-date',title='standard input',&END
!#########################################################################
&DEFN action='open file',file='engine.list',&END
&DEFN action='open file',file='helicopter.list',&END
!=========================================================================
&DEFN quant='Cases',&END
&VALUE title='Helicopter',TASK_size=0,TASK_mission=1,TASK_perf=1,&END
&DEFN quant='Size',&END
&VALUE nFltCond=0,nMission=0,&END
!=========================================================================
&DEFN quant='OffDesign',&END
&VALUE title='mission analysis',nMission=1,&END
&DEFN quant='OffMission',&END
&VALUE
        (one mission, mission segment parameters as arrays)
&END
!=========================================================================
&DEFN quant='Performance',&END
&VALUE title='performance analysis',nFltCond=2,&END
&DEFN quant='PerfCondition',&END
&VALUE
        (one condition)
&END
&DEFN quant='PerfCondition',&END
&VALUE
        (one condition)
&END
!=========================================================================
&DEFN action='endofcase',&END
!#########################################################################
&DEFN action='endofjob',&END
```

Figure 1-3a Illustration of NDARC input (primary input).

```
&DEFN action='ident',created='time-date',title='Helicopter',&END
!#########################################################################
! default helicopter
&DEFN action='configuration',&END
&VALUE config='helicopter',rotate=1,&END
!=========================================================================
&DEFN quant='Cases',&END
&VALUE title='Helicopter',FILE_design='helicopter.design',&END
&DEFN quant='Size',&END
&VALUE
    title='Helicopter',
    SIZE_perf='none',SET_rotor='radius+Vtip+sigma','radius+Vtip+sigma',
    FIX_DGW=1,SET_tank='input',SET_SDGW='input',SET_WMTO='input',
&END
&DEFN quant='Solution',&END
&VALUE &END
!=========================================================================
&DEFN quant='Aircraft',&END
&VALUE (Aircraft parameters) &END
&DEFN quant='Geometry',&END
&VALUE (geometry) &END
&DEFN quant='Rotor 1',&END
&VALUE (Rotor 1 parameters) &END
!=========================================================================
        (other parameters in other structures)
!=========================================================================
&DEFN quant='TechFactors',&END
&VALUE (technology factors) &END
!#########################################################################
&DEFN action='endoffile',&END
```

Figure 1-3b Illustration of NDARC input (secondary input file).

1–2 NDARC Input and Output

Figure 1-2 illustrates the input and output environment of NDARC. Table 1-1 lists the possible input and output files. A job reads input from one or more files. The primary input is obtained from standard input (perhaps redirected to a file). The primary input can direct the code to read other files, identified by file name or logical name. The input data are read in namelist format. Unit numbers are part of the job input. Output file names are part of the case input. Input files names are defined in the input itself.

Table 1-1. Input and output files.

	file logical name	unit number (and default)
INPUT		
Primary Input	standard input	nuin = 5
Secondary Input File	FILE	nufile = 40
Aircraft Description	FILE	nufile = 40
Solution	FILE	nufile = 40
OUTPUT		
Output	standard output	nuout = 6
Design	DESIGNn	nudesign = 41
Performance	PERFn	nuperf = 42
Airframe Aerodynamics	AEROn	nuaero = 43
Engine Performance	ENGINEn	nuengine = 44
Geometry	GEOMETRYn	nugeom = 45
Aircraft Description	AIRCRAFTn	nuacd = 46
Solution	SOLUTIONn	nusoln = 47
Sketch	SKETCHn	nusketch = 48
Errors	ERRORn	nuerror = 49

1-2.1 Input

Figure 1-3 illustrates NDARC input. The primary input starts with a JOB namelist, then DEFN namelists are read to define the action and contents of the subsequent information. The job parameters include initialization control, error action, and input/output unit numbers. Job parameters can be read during case input using QUANT='Job'. The initialization takes place before case input, so changed initialization parameters in QUANT='Job' input take effect for the next case. The DEFN namelist has the following parameters.

a) ACTION: character string (length = 32; case independent).

b) QUANT: character string (length = 32, case independent); corresponds to data structure in input; string includes structure number (1 or next condition/mission if absent).

c) SOURCE: integer; for copy action.

d) FILE: file name or logical name (length = 256).

e) CREATED: character string of creation time and date (length = 20).

f) TITLE: character string of title identifying input file (length = 80).

g) VERSION: code version number as character string (length = 6).

h) MODIFICATION: character string of code modification (length = 32).

Table 1-2 describes the options for the ACTION variable in the DEFN namelist. The code searches for the keyword in the ACTION character string. A solution file (text or binary) can be written by an NDARC job and then read by a subsequent job, restoring the solution to the state that existed when the file was created. Then additional output and additional cases can be obtained. An aircraft description file can be written by an NDARC job and then read by a subsequent job, restoring the aircraft model (but not the solution). A secondary input file has DEFN namelists to define action and contents. When ACTION='end' (or EOF) is encountered in a secondary input file, the file is closed and the code returns to primary input.

A DEFN namelist with ACTION='ident' identifies the file; probably there is only one identification per file, and only the last occurrence is stored. The identification consists of the CREATED, TITLE, VERSION, MODIFICATION variables. CREATED and TITLE are written when a file is created by NDARC, and read and stored for each input file. If present, VERSION and MODIFICATION are compared with the version and modification of the code, and input continues only if they match.

The parameter QUANT identifies the data structure to be read (namelist format), initialized, or copied. Table 1-3 describes the options. The input corresponds to the data structures of the analysis. The QUANT string includes the structure number; if absent, the number is 1, or the next condition or mission. Note that each mission, with the mission segment parameters as arrays, is input with QUANT='SizeMission' or QUANT='OffMission'; and each condition is input with QUANT='SizeCondition' or QUANT='PerfCondition'.

A case inherits input for flight conditions and missions from the previous case if INIT_input = last-case-input (default). A DEFN namelist with ACTION='delete' deletes this input as specified by QUANT='SizeCondition n', QUANT='SizeMission n', QUANT='OffMission n', or QUANT='PerfCondition n'. ACTION='delete all' deletes all (ignore structure number); ACTION='delete one' deletes structure n (all if number absent); ACTION='delete last' deletes structure n and subsequent structures (all if number absent).

For ACTION='nosize', input variables in the Size structure are set for no size iteration: SIZE_perf='none', SIZE_engine='none', SIZE_jet='none', SIZE_charge='none', SET_rotor='radius+Vtip+sigma', SET_wing='area+span', FIX_DGW=1, SET_tank='input', SET_limit_ds='input', SET_SDGW='input', SET_WMTO='input'.

Table 1-2. ACTION options.

ACTION	keyword	QUANT	function
Primary Input Only			
blank	—	blank	open and read secondary input file, name = FILE
'open file'	file, open		open and read secondary input file, name = FILE
'load aircraft'	aircraft, desc		load aircraft description file, name = FILE
'read solution'	solution	'text'	read complete solution file, name = FILE (text)
'read solution'	solution	not 'text'	read complete solution file, name = FILE (binary)
'end of case'	end+case		stop case input, execute case
'end of job'	end+job, quit		stop job input, execute case, exit code
Primary or Secondary Input			
blank	—	'structure'	read VALUE namelist
'read namelist'	list	'structure'	read VALUE namelist
'copy input'	copy	'structure'	copy input from source (same structure), SOURCE=SRCnumber
'initialize'	init	'structure'	set structure variables to default values
'delete all'	del+all	'structure'	delete all conditions or missions
'delete one'	del+one	'structure'	delete one condition or mission
'delete last'	del+last	'structure'	delete last conditions or missions
'configuration'	config		set input based on aircraft configuration
'nosize'	nosize		set input for no size iteration
'identification'	ident		identify file
'end'	end (or EOF)		Secondary: close file, return to primary input
'end'	end (or EOF)		Primary: same as ACTION='endofjob'

Table 1-3. QUANT options.

QUANT	data structures read	maximum n
'Job'	Job	
'Cases'	Cases	
'Size'	SizeParam	
'SizeCondition n'	one FltCond+FltState	nFltCond
'SizeMission n'	one MissParam, MissSeg+FltState as array	nMission
'OffDesign'	OffParam	
'OffMission n'	one MissParam, MissSeg+FltState as array	nMission
'Performance'	PerfParam	
'PerfCondition n'	one FltCond+FltState	nFltCond
'MapEngine'	MapEngine	
'MapAero'	MapAero	
'Solution'	Solution	
'Cost'	Cost	
'Emissions'	Emissions	
'Aircraft'	Aircraft	
'Systems'	Systems, WFltCont, WDeIce	
'Fuselage'	Fuselage, AFuse, WFuse	
'LandingGear'	LandingGear, AGear, WGear	
'Rotor n'	Rotor, PRotorInd, PRotorPro, PRotorTab, IRotor, DRotor, WRotor	nRotor
'Wing n'	Wing, AWing, WWing, WWingTR	nWing
'Tail n'	Tail, ATail, WTail	nTail
'FuelTank n'	FuelTank, WTank	nTank
'Propulsion n'	Propulsion, WDrive	nPropulsion
'EngineGroup n'	EngineGroup, DEngSys, WEngSys	nEngineGroup
'JetGroup n'	JetGroup, DJetSys, WJetSys	nJetGroup
'ChargeGroup n'	ChargeGroup, DChrgSys, WChrgSys	nChargeGroup
'EngineModel n'	EngineModel	nEngineModel
'EngineParamN n'	EngineParamN	nEngineParamN
'EngineTable n'	EngineTable	nEngineTable
'RecipModel n'	RecipModel	nRecipModel
'CompressorModel n'	CompressorModel	nCompressorModel
'MotorModel n'	MotorModel	nMotorModel
'JetModel n'	JetModel	nJetModel
'FuelCellModel n'	FuelCellModel	nFuelCellModel
'SolarCellModel n'	SolarCellModel	nSolarCellModel
'BatteryModel n'	BatteryModel	nBatteryModel
'TechFactors'	all TECH_xxx	
'Geometry'	all Location	

1-2.2 Formats

Namelist input has the following format (see also figure 1-3).

```
&DEFN action='IDENT',created='time-date',title='xxx',version='n.n',modification='xxx',&END
&DEFN quant='STRUCTURE n',&END
&VALUE param=value,&END
&DEFN action='NAMELIST',quant='STRUCTURE n',&END
&VALUE param=value,&END
&DEFN action='COPY',quant='STRUCTURE n',source=#,&END
```

An aircraft description file is written in a separate file by NDARC, from theDesign(kcase):

```
&DEFN action='IDENT',created='time-date',title='xxx',version='n.n',modification='xxx',&END
&VALUE_ADIMEN nrotor=m,nwing=m,ntail=m,ntank=m,npropulsion=m,nenginegroup=m,njetgroup=m,nchargegroup=m,
     nenginemodel=m,nengineparamn=m,nenginetable=m,nrecipmodel=m,ncompressormodel=m,nmotormodel=m,njetmodel=m,
     nfuelcellmodel=m,nsolarcellmodel=m,nbatterymodel=m,&END
&VALUE theStructure%xxx,&END
&VALUE theStructure%xxx,&END
&VALUE theStructure%xxx,&END
```

This aircraft description file is read by identifying it in the primary input:

```
&DEFN action='AIRCRAFT',file='aircraft.acd',&END
```

A solution file is written in a separate file by NDARC, from theDesign(kcase), in binary or text format:

```
&DEFN action='IDENT',created='time-date',title='xxx',version='n.n',modification='xxx',&END
&VALUE_ADIMEN nrotor=m,nwing=m,ntail=m,ntank=m,npropulsion=m,nenginegroup=m,njetgroup=m,nchargegroup=m,
     nenginemodel=m,nengineparamn=m,nenginetable=m,nrecipmodel=m,ncompressormodel=m,nmotormodel=m,njetmodel=m,
     nfuelcellmodel=m,nsolarcellmodel=m,nbatterymodel=m,&END
&VALUE_SDIMEN nsizecond=m,nsizemiss=m,nperfcond=m,noffmiss=m,&END
&VALUE theStructure%xxx,&END
&VALUE theStructure%xxx,&END
&VALUE theStructure%xxx,&END
```

This solution file is read by identifying it in the primary input, with QUANT identifying the file as text or binary:

```
&DEFN action='SOLUTION,quant='TEXT',file='aircraft.soln'&END
```

1-2.3 Conventions

Each flight condition (FltCond and FltState variables) is input in a separate SizeCondition or PerfCondition namelist.

Each mission (MissParam, MissSeg, and FltState variables) is input in a separate SizeMission or OffMission namelist. All mission segments are defined in this namelist, so MissSeg and FltState variables are arrays. Each variable gets one more dimension, with the first array index always segment number.

Geometry input includes Location variables, which are read as elements of the data structure (for example, loc_rotor%SL).

Variables can appear in more than one namelist. Specifically there are separate namelists for all technology factors (all TECH_xxx variables), and all geometry (all Location variables), with corresponding options for output. A variable that is a scalar in the Rotor, Wing, Tail, Propulsion, EngineGroup, JetGroup, or ChargeGroup input becomes an array in the TechFactors or Geometry input. Note that it is the Location variable that is the array (for example, loc_rotor(1)%SL).

Case is not important in character string input. Character string input consists of keywords; the code searches for the keywords in the string.

Default values are specified in the dictionary (blank implies a default of zero); all elements of arrays have the same default value.

Tasks, aircraft, and components have title variables. There are also notes variables (long character string) to record information about the input.

1–3 Software Tool

All information about data structures is contained in a dictionary file. This information includes the parameter name, dimension, type, default value, description, identification as input, and formats for write of the parameter. A software tool was created to manage the data, including construction of the module of data structures. The software tool reads this dictionary file and creates subroutines for the input process: namelist read, copy, print of input, initialization, set to default. This software tool is a program that manipulates character strings, to produce compilable module and subroutines for NDARC.

1–4 Data Structures

Table 1-4 outlines the data structures used for NDARC. The following chapters describe the contents of each structure. Note that a ”+” sign in the column between the type and description identifies input variables. Input variables can be changed by the analysis, so may not be the same at the end of a case as at the beginning. All variables, input and other, are initialized to zero or blank. If default values exist (only for input variables), they supersede that initialization.

Table 1-4. NDARC data structures.

Design	Fuselage	FuelTank(ntankmax)	FltState(nfltmax)
Cases	[Location]loc_fuselage	[Location]loc_auxtank(nauxtankmax)	FltAircraft
Size	AFuse	Weight	FltFuse
SizeParam	Weight	WTank	FltGear
FltCond(nfltmax)	WFuse	Propulsion(npropmax)	FltRotor(nrotormax)
FltState(nfltmax)	LandingGear	Weight	FltWing(nwingmax)
Mission(nmissmax)	[Location]loc_gear	WDrive	FltTail(ntailmax)
MissParam	AGear	EngineGroup(nengmax)	FltTank(ntankmax)
MissSeg(nsegmax)	Weight	[Location]loc_engine	FltProp(npropmax)
FltState(nsegmax)	WGear	DEngSys	FltEngn(nengmax)
OffDesign	Rotor(nrotormax)	Weight	FltJet(njetmax)
OffParam	[Location]loc_rotor	WEngSys	FltChrg(nchrgmax)
Mission(nmissmax)	[Location]loc_pylon	JetGroup(njetmax)	
MissParam	[Location]loc_pivot	[Location]loc_jet	
MissSeg(nsegmax)	[Location]loc_nac	DJetSys	
FltState(nsegmax)	PRotorInd	Weight	
Performance	PRotorPro	WJetSys	
PerfParam	PRotorTab	ChargeGroup(nchrgmax)	
FltCond(nfltmax)	IRotor	[Location]loc_charger	
FltState(nfltmax)	DRotor	DChrgSys	
MapEngine	Weight	Weight	
MapAero	WRotor	WChrgSys	
Solution	Wing(nwingmax)	EngineModel(nengmax)	
Cost	[Location]loc_wing	EngineParamN(nengpmax)	
Emissions	AWing	EngineTable(nengmax)	
Aircraft	Weight	RecipModel(nengmax)	
[Location]loc_cg	WWing	CompressorModel(nengmax)	
Weight	WWingTR	MotorModel(nengmax)	
XAircraft	Tail(ntailmax)	JetModel(njetmax)	
Systems	[Location]loc_tail	FuelCellModel(nchrgmax)	
Weight	ATail	SolarCellModel(nchrgmax)	
WFltCont	Weight	BatteryModel(ntankmax)	
WDeIce	WTail		

Chapter 2

Input Based on Configuration

The rotorcraft configuration is identified by the variable config in the QUANT='Aircraft' input. With ACTION='configuration', the analysis defines a number of input parameters in order to facilitate modelling of conventional configurations. The input required to execute ACTION='configuration' is:

```
&DEFN action='configuration',&END
&VALUE config='aaaa',nRotor=#,rotate=#,#,overlap_tandem=#,#,ang_multicopter=#,#,&END
```

The VALUE namelist contains only the parameters Aircraft%config (rotorcraft configuration), Aircraft%nRotor (number of rotors, only for multicopter), Rotor%rotate (direction of rotation, each rotor), Rotor%overlap_tandem (each rotor, only for tandem helicopter), and Rotor%ang_multicopter (each rotor, only for multicopter). The convention is that the first rotor is the main rotor for the helicopter or compound configuration; the front rotor for the tandem configuration; the right rotor for the tiltrotor configuration. This capability has been implemented for rotorcraft, helicopter, tandem, coaxial, tiltrotor, compound, multicopter, and airplane configurations. There is common input for all configurations, and special input for each except the rotorcraft. The analysis creates the following input, through information at the end of the NDARC structures file. Note that default values are defined for all input quantities.

2–1 All Configurations

a) Components: nRotor=2 (except multicopter), nWing=0, nTail=2; nPropulsion=1, nEngineGroup=1, nEngineModel=1, nJetGroup=0, nChargeGroup=0

b) Aircraft
Aircraft controls: ncontrol=7, IDENT_control='coll','latcyc','lngcyc','pedal','tailinc','elevator','rudder'
Control states: nstate_control=1
Trim states: nstate_trim=10, selected by FltAircraft%STATE_trim=IDENT_trim; compound state not active

	IDENT_trim	mtrim	trim_quant	trim_var
6-variable	'free'	6	'force x','force y','force z','moment x','moment y','moment z'	'coll','latcyc','lngcyc','pedal','pitch','roll'
longitudinal	'long'	4	'force x','force z','moment y','moment z'	'coll','lngcyc','pitch','pedal'
symmetric 3-variable	'symm'	3	'force x','force z','moment y'	'coll','lngcyc','pitch'
weight and drag	'force'	2	'force x','force z'	'coll','pitch'
hover thrust and torque	'hover'	2	'force z','moment z'	'coll','pedal'
hover thrust	'thrust'	1	'force z'	'coll'
hover rotor C_T/σ	'rotor'	1	'CTs rotor 1'	'coll'
wind tunnel	'windtunnel'	3	'CTs rotor 1','betac 1','betas 1'	'coll','latcyc','lngcyc'
full power	'power'	1	'P margin 1'	'coll'
ground run	'ground'	1	'force x'	'coll'
compound	'comp'	6	'force x','force y','force z','moment x','moment y','moment z'	'coll','latcyc','lngcyc','pedal','prop','roll'

c) Systems: MODEL_FWfc=0, MODEL_CVfc=0 (no fixed wing flight controls, no conversion controls)

d) Landing Gear: KIND_LG=0 (fixed gear), Wgear%nLG=3

e) Fuel Tank: place=1 (internal tank), Mauxtanksize=1, WTank%ntank_int=1, WTank%nplumb=2

f) Rotor
First rotor is primary: kPropulsion=1, KIND_xmsn=1
Second and other rotors are dependent: kPropulsion=1, KIND_xmsn=0, INPUT_gear=1 (input quantity is tip speed)
Configuration: direction='main'
Drag: SET_aeroaxes=1 (helicopter), Idrag=0. (not tilt); DRotor%SET_Dspin=1, DRotor%DoQ_spin=0. (no spinner drag)
Weight: WRotor%MODEL_config=1 (rotor), WRotor%KIND_rotor=2 (not tilting)
Control:
INPUT_coll=0, INPUT_cyclic=0, INPUT_incid=0, INPUT_cant=0, INPUT_diam=0 (no connection to aircraft controls)
T_coll=0., T_latcyc=0., T_lngcyc=0., T_incid=0., T_cant=0., T_diam=0. (all controls, all states)
KIND_control=1 (1 for thrust and TPP command)
KIND_coll=2 (1 for thrust, 2 for C_T/σ)
KIND_cyclic=1 (1 for TPP tilt, 2 for hub moment, 3 for lift offset)
KIND_tilt=0 (fixed shaft)

g) Wing
Control:
INPUT_flap=0, INPUT_flaperon=0, INPUT_aileron=0, INPUT_incid=0 (no connection to aircraft controls)
T_flap=0., T_flaperon=0., T_aileron=0., T_incid=0. (all controls, all states, all panels)
Drag: Idrag=0. (not tilt)

h) Tail
First tail is horizontal tail: KIND_tail=1, WTail%MODEL_Htail=1 (helicopter)
Second tail is vertical tail: KIND_tail=2, WTail%MODEL_Vtail=1 (helicopter)
Configuration: KIND_TailVol=2, TailVolRef=1 (rotor reference)
Control:
INPUT_cont=1 (tail control connection to aircraft controls), INPUT_incid=0 (no connection of tail incidence to aircraft controls)
T_cont=0., T_incid=0. (all controls, all states)

i) Propulsion: nGear=1, STATE_gear_wt=1, INPUT_DN=0

j) Engine Group
Configuration: kPropulsion=1, INPUT_gear=1 (gear ratio from N_spec), SET_power=0 (sized), fPsize=1., direction='x', SET_geom=0 (standard position)
Drag: MODEL_drag=1, Idrag=0. (not tilt)

k) Engine Group, Jet Group, Charge Group
Control:
INPUT_amp=0, INPUT_mode=0, INPUT_incid=0, INPUT_yaw=0 (no connection to aircraft controls)
T_amp=0., T_incid=0., T_yaw=0. (all controls, all states)

2–2 Helicopter

a) Rotor
First rotor is main rotor: config='main', fDGW=1., fArea=1., SET_geom='standard'
rotation: $r = 1$; if (Rotor(1)%rotate < 0) $r = -1$
control: INPUT_coll=1, INPUT_latcyc=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)
control: T_coll(1,1)=1., T_latcyc(2,1)= $-r$, T_lngcyc(3,1)=-1.
Second rotor is tail rotor: config='tail+antiQ', fThrust=1., fArea=0., SET_geom='tailrotor', mainRotor=1
direction='tail', WRotor%MODEL_config=2 (tail rotor)
rotation: $r = 1$; if (Rotor(1)%rotate < 0) $r = -1$
control: KIND_control=2 (thrust and NFP command); INPUT_coll=1, T_coll(4,1)= $-r$ (rotor collective connection to aircraft control 'pedal')
Performance: PRotorInd%MODEL_twin='none'
Drag: SET_Sspin=1, Swet_spin=0., DRotor%SET_Dspin=1, DRotor%DoQ_spin=0., DRotor%CD_spin=0. (no spinner drag)

b) Tail
Control: INPUT_incid=1 (tail incidence connection to aircraft controls)
Horizontal tail: T_incid(5,1)=1. (incidence connection to aircraft control 'tailinc'), T_cont(6,1)=1. (elevator direct control)
Vertical tail: T_cont(7,1)=1. (rudder direct control)

c) Propulsion: WDrive%ngearbox=2, WDrive%ndriveshaft=1, WDrive%fShaft=0.1, WDrive%fTorque=0.03, WDrive%fPower=0.15

2–3 Tandem

a) Components: nTail=0 (no tail)

b) Fuel Tank: place=2 (sponson)

c) Rotor
Configuration: config='main+tandem', fDGW=.5, SET_geom='tandem', fRadius=1.
fArea=$1-m/2$, from $m=(2/\pi)(\cos^{-1}h-h\sqrt{1-h^2})$, $h=1-$ overlap_tandem
First rotor is front rotor: otherRotor=2
rotation: $r=1$, if (Rotor(1)%rotate <0) $r=-1$
control: INPUT_coll=1, INPUT_latcyc=1 (rotor control connection to aircraft controls)
control: T_coll(1,1)=1., T_coll(3,1)=-1., T_latcyc(2,1)=$-r$, T_latcyc(4,1)=$-r$
Second rotor is aft rotor: otherRotor=1, rotate=-Rotor(1)%rotate
rotation: $r=1$, if (Rotor(1)%rotate <0) $r=-1$; $r=-r$
control: INPUT_coll=1, INPUT_latcyc=1 (rotor control connection to aircraft controls)
control: T_coll(1,1)=1., T_coll(3,1)= 1., T_latcyc(2,1)=$-r$, T_latcyc(4,1)=r
Performance: PRotorInd%MODEL_twin='tandem', PRotorInd%Kh_twin=1., PRotorInd%Kf_twin=0.85, IRotor%MODEL_int_twin=2
Drag: SET_Sspin=1, Swet_spin=0., DRotor%SET_Dspin=1, DRotor%DoQ_spin=0., DRotor%CD_spin=0. (no spinner drag)

d) Propulsion: WDrive%ngearbox=2, WDrive%ndriveshaft=1, WDrive%fShaft=0.1; WDrive%fTorque=0.6, WDrive%fPower=0.6

2–4 Coaxial

a) Rotor
Configuration: config='main+coaxial', fDGW=.5, fArea=.5, SET_geom='coaxial', fRadius=1.
First rotor is lower rotor: otherRotor=2
rotation: $r=1$, if (Rotor(1)%rotate <0) $r=-1$
control: INPUT_coll=1, INPUT_latcyc=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)
control: T_coll(1,1)=1., T_coll(4,1)=r, T_latcyc(2,1)=$-r$, T_lngcyc(3,1)=-1.
Second rotor is upper rotor: otherRotor=1, rotate=-Rotor(1)%rotate
rotation: $r=1$, if (Rotor(1)%rotate <0) $r=-1$; $r=-r$
control: INPUT_coll=1, INPUT_latcyc=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)
control: T_coll(1,1)=1., T_coll(4,1)=r, T_latcyc(2,1)=$-r$, T_lngcyc(3,1)=-1.
Performance: PRotorInd%MODEL_twin='coaxial', PRotorInd%Kh_twin=1., PRotorInd%Kf_twin=0.85, IRotor%MODEL_int_twin=2
Drag: SET_Sspin=1, Swet_spin=0., DRotor%SET_Dspin=1, DRotor%DoQ_spin=0., DRotor%CD_spin=0. (no spinner drag)

b) Tail
Horizontal tail: T_cont(6,1)=1. (elevator direct control)
Vertical tail: T_cont(7,1)=1. (rudder direct control)

c) Propulsion: WDrive%ngearbox=1, WDrive%ndriveshaft=0, WDrive%fShaft=0.1; WDrive%fTorque=0.6, WDrive%fPower=0.6

2–5 Tiltrotor

a) Components: nWing=1, nEngineGroup=2 (engine at each nacelle)

b) Aircraft
Aircraft controls: ncontrol=10, IDENT_control='coll','latcyc','lngcyc','pedal','tilt','flap','flaperon','elevator','aileron','rudder'
Control states: nstate_control=2 (state 1 for helicopter mode, state 2 for airplane mode)
Control state in conversion: kcont_hover=1, kcont_conv=1, kcont_cruise=2
Drive state in conversion: kgear_hover(1)=1, kgear_conv(1)=1, kgear_cruise(1)=1

c) Systems: MODEL_FWfc=1, MODEL_CVfc=1 (fixed wing flight controls, conversion control)

d) Landing Gear: KIND_LG=1 (retractable)

e) Fuel Tank: place=3 (wing), fFuelWing(1)=1.

f) Rotor
Configuration: config='main+tiltrotor', fDGW=.5, fArea=1.; SET_geom='tiltrotor', KIND_TRgeom=1 (from clearance), fRadius=1., WingForRotor=1
First rotor is right rotor: otherRotor=2
  helicopter mode control: INPUT_coll=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)
  helicopter mode control: T_coll(1,1)=1., T_coll(2,1)=-1., T_lngcyc(3,1)=-1., T_lngcyc(4,1)=1.
Second rotor is left rotor: otherRotor=1, rotate=-Rotor(1)%rotate; INPUT_gear=2 (input quantity is gear ratio)
  helicopter mode control: INPUT_coll=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)
  helicopter mode control: T_coll(1,1)=1., T_coll(2,1)=1., T_lngcyc(3,1)=-1., T_lngcyc(4,1)=-1.
Airplane mode control state: T_coll(1,2)=1. (collective connection to aircraft control 'coll')
Tilt: KIND_tilt=1 (shaft control = incidence), incid_ref=90. (helicopter mode reference), SET_Wmove=1, fWmove=1. (wing tip weight move)
  control: INPUT_incid=1, T_incid(5,1)=1., T_incid(5,2)=1. (incidence connection to aircraft control 'tilt')
Performance: PRotorInd%MODEL_twin='tiltrotor', PRotorInd%Kh_twin=1., PRotorInd%Kf_twin=1., IRotor%MODEL_int_twin=2
Weight: WRotor%KIND_rotor=1 (tilting)
Drag: SET_aeroaxes=2 (tiltrotor), Idrag=90. (tiltrotor)
  DRotor%SET_Dhub=1, DRotor%DoQ_hub=0., DRotor%CD_hub=0., DRotor%SET_Vhub=1, DRotor%DoQV_hub=0., DRotor%CDV_hub=0. (no hub drag)

g) Wing
Configuration: fDGW=1., nRotorOnWing=2, RotorOnWing(1)=1, RotorOnWing(2)=2, SET_ext=0
Control: KIND_flaperon=3 (independent), nVincid=1
  INPUT_flap=1, INPUT_flaperon=1, INPUT_aileron=1 (wing control connection to aircraft controls)
  T_aileron(2,2)=-1. (airplane mode aileron connection to aircraft control 'latcyc')

T_flap(6,1)=1., T_flap(6,2)=1. (flap direct control)
T_flaperon(7,1)=1., T_flaperon(7,2)=1. (flaperon direct control)
T_aileron(9,1)=1., T_aileron(9,2)=1. (aileron direct control)
Weight: WWing%MODEL_wing=3 (tiltrotor)

h) Tail
Configuration: KIND_TailVol=1, TailVolRef=1 (wing reference); Wtail%MODEL_Htail=2, Wtail%MODEL_Vtail=2 (tiltrotor)
Horizontal tail control: nVincid=1
T_cont(3,2)=1. (airplane mode elevator connection to aircraft control 'lngcyc')
T_cont(8,1)=1., T_cont(8,2)=1. (elevator direct control)
Vertical tail control: nVincid=1
T_cont(4,2)=1. (airplane mode rudder connection to aircraft control 'pedal')
T_cont(10,1)=1., T_cont(10,2)=1. (rudder direct control)

i) Propulsion: WDrive%ngearbox=2, WDrive%ndriveshaft=1, WDrive%fShaft=0.1; WDrive%fTorque=0.6, WDrive%fPower=0.6

j) Engine Group
Configuration: fPsize=0.5, SET_geom=1 (tiltrotor)
First engine group: RotorForEngine=1
Second engine group: RotorForEngine=2
Control: INPUT_incid=1; T_incid(5,1)=1., T_incid(5,2)=1. (nacelle incidence connection to aircraft control 'tilt')
Drag: SET_Swet=1, Swet=0., MODEL_drag=0, Idrag=90. (no engine nacelle drag)
DEngSys%SET_drag=1, DEngSys%DoQ=0., DEngSys%CD=0.; DEngSys%SET_Vdrag=1, DEngSys%DoQV=0., DEngSys%CDV=0.

2–6 Compound

a) Components: nRotor=3, nWing=1

b) Aircraft
Aircraft controls: ncontrol=10, IDENT_control='coll','latcyc','lngcyc','pedal','tailinc','elevator','rudder','prop','aileron','flap'
Trim states: nstate_trim=11; compound state active

c) Rotor
First rotor is main rotor: config='main', fDGW=1., fArea=1., SET_geom='standard'
rotation: $r = 1$; if (Rotor(1)%rotate < 0) $r = -1$
control: INPUT_coll=1, INPUT_latcyc=1, INPUT_lngcyc=1 (rotor control connection to aircraft controls)

control: T_coll(1,1)=1., T_latcyc(2,1)= $-r$, T_lngcyc(3,1)=-1.
Second rotor is tail rotor: config='tail+antiQ', fThrust=1., fArea=0., SET_geom='tailrotor', mainRotor=1
direction='tail', WRotor%MODEL_config=2 (tail rotor)
rotation: $r = 1$; if (Rotor(1)%rotate < 0) $r = -1$
control: KIND_control=2 (thrust and NFP command); INPUT_coll=1, T_coll(4,1)= $-r$ (rotor collective connection to aircraft control 'pedal')
Third rotor is propeller: config='prop+auxT', fThrust=1., fArea=0., SET_geom='standard'
direction='prop', WRotor%MODEL_config=3 (auxiliary thrust)
control: KIND_control=2 (thrust and NFP command); INPUT_coll=1, T_coll(8,1)=1. (rotor collective connection to aircraft control 'prop')
Performance: PRotorInd%MODEL_twin='none'
Drag: SET_Sspin=1, Swet_spin=0., DRotor%SET_Dspin=1, DRotor%DoQ_spin=0., DRotor%CD_spin=0. (no spinner drag)

d) Wing
Configuration: fDGW=1.
Control: nVincid=1
INPUT_flap=1, INPUT_flaperon=1, INPUT_aileron=1 (wing control connection to aircraft controls)
T_aileron(9,1)=1. (aileron direct control)
T_flap(10,1)=1. (flap direct control)
Weight: WWing%MODEL_wing=2 (parametric)

e) Tail
Control: INPUT_incid=1 (tail incidence connection to aircraft controls)
Horizontal tail: T_incid(5,1)=1. (incidence connection to aircraft control 'tailinc'), T_cont(6,1)=1. (elevator direct control)
Vertical tail: T_cont(7,1)=1. (rudder direct control)

f) Propulsion: WDrive%ngearbox=3, WDrive%ndriveshaft=1, WDrive%fShaft=0.1, WDrive%fTorque=0.03, WDrive%fPower=0.15

2–7 Multicopter

a) Components: nTail=0 (no tail)

b) Rotor
Configuration: config='main+multirotor', fDGW=1/nRotor, fArea=1., SET_geom='multicopter'
Control: KIND_control=2 (thrust and NFP command); INPUT_coll=1
rotation: $r = 1$; if (rotate < 0) $r = -1$; a =ang_multicopter
T_coll(1,1)=1., T_coll(2,1)=$-\sin(a)$, T_coll(3,1)=$\cos(a)$, T_coll(4,1)=r (rotor collective connection to aircraft controls)

Performance: PRotorInd%MODEL_twin='multirotor'; xh_multi=0., xp_multi=0., xf_multi=0., except 1.0 for this rotor
Drag: SET_Sspin=1, Swet_spin=0., DRotor%SET_Dspin=1, DRotor%DoQ_spin=0., DRotor%CD_spin=0. (no spinner drag)

c) Propulsion: WDrive%ngearbox=nRotor, WDrive%ndriveshaft=nRotor-1, WDrive%fShaft=0.1; WDrive%fTorque=0.6, WDrive%fPower=0.6

2–8 Airplane

a) Components: nRotor=1, nWing=1

b) Solution: KIND_Lscale=2 (wing span reference)

c) Aircraft
Geometry: INPUT_geom=2, KIND_scale=2, kScale=1 (geometry scaled with wing span); KIND_Ref=2, kRef=1 (wing reference)
Aircraft controls: ncontrol=9, IDENT_control='coll','latcyc','lngcyc','pedal','tailinc','elevator','rudder','aileron','flap'
coll = propeller, latcyc = lateral stick, lngcyc = longitudinal stick

d) Systems: MODEL_FWfc=1 (fixed wing flight controls)

e) Rotor
Propeller: config='prop+auxT', fThrust=1., fDGW=0., SET_geom='standard'
direction='prop', WRotor%MODEL_config=3 (auxiliary thrust)
Control: KIND_control=2 (thrust and NFP command); INPUT_coll=1, T_coll(1,1)=1. (rotor collective connection to aircraft control 'coll')

f) Wing
Configuration: fDGW=1.
Control: nVincid=1
INPUT_flap=1, INPUT_aileron=1 (wing control connection to aircraft controls)
T_aileron(2,1)=1. (lateral stick), T_aileron(8,1)=1. (aileron direct control)
T_flap(9,1)=1. (flap direct control)
Weight: WWing%MODEL_wing=2 (parametric)

g) Tail: KIND_TailVol=1, TailVolRef=1 (wing reference)
Control: INPUT_incid=1 (tail incidence connection to aircraft controls)
Horizontal tail: T_incid(5,1)=1. (incidence connection to aircraft control 'tailinc'), T_cont(3,1)=1. (longitudinal stick), T_cont(6,1)=1. (elevator direct control)
Vertical tail: T_cont(4,1)=1. (pedal), T_cont(7,1)=1. (rudder direct control)

h) Propulsion: WDrive%ngearbox=1, WDrive%ndriveshaft=1, WDrive%fShaft=0.1

Chapter 3

Parameters and Constants

Parameters	Value				
ncasemax	10	ndesignmax	41	ngetab2max	20
nfilemax	40	ncontmax	20	npanelmax	5
nrotormax	16	nsweepmax	200	nauxtankmax	4
npropmax	16	qsweepmax	4	ngearmax	8
nengmax	16	ntrimstatemax	20	nratemax	20
njetmax	4	mtrimmax	16	nengtmax	20
nchrgmax	4	nvnemax	32	nengxmax	100
nstatemax	10	niasmax	40	nengkmax	6
nwingmax	8	nvelmax	20	nengrmax	40
ntailmax	6	ntablemax	32	nengpmax	20
ntankmax	4	nrmax	51	nengcmax	80
nmissmax	20	mrmax	40	nspeedmax	8
nsegmax	40	mpsimax	36	nrowmax	4000
nfltmax	21	ngetabmax	40	naeromax	100

Constants	Value				
ACTION_error	0	SET_takeoff_transition	6	TRIM_QUANT_Cmargin	20
ACTION_file	1	SET_takeoff_climb	7	TRIM_QUANT_tank	21
ACTION_ident	2	SET_takeoff_brake	8	TRIM_QUANT_Bmargin	22
ACTION_list	3	MAX_QUANT_none	0	TRIM_QUANT_rotorL	23
ACTION_copy	4	MAX_QUANT_end	1	TRIM_QUANT_rotorfL	24
ACTION_init	5	MAX_QUANT_range	2	TRIM_QUANT_CLs	25
ACTION_delete	6	MAX_QUANT_rangelow	3	TRIM_QUANT_rotorV	26
ACTION_delone	7	MAX_QUANT_range100	4	TRIM_QUANT_rotorX	27
ACTION_dellast	8	MAX_QUANT_rangeVg	5	TRIM_QUANT_rotorfX	28

ACTION_config	9
ACTION_nosize	10
ACTION_desc	11
ACTION_soln	12
ACTION_endfile	13
ACTION_endcase	14
ACTION_endjob	15
STATE_newcase	1
STATE_onecase	2
STATE_endofjob	3
STATE_init	1
STATE_size	2
STATE_miss	3
STATE_perf	4
STATE_maps	5
STATE_out	6
SIZE_perf_engine	1
SIZE_perf_rotor	2
SIZE_perf_none	3
SIZE_engine_engn	1
SIZE_engine_none	2
SIZE_jet_jet	1
SIZE_jet_none	2
SIZE_charge_chrg	1
SIZE_charge_none	2
SIZE_rotor_none	1
SIZE_rotor_radius	2
SIZE_rotor_thrust	3
SET_rotor_radius	1
SET_rotor_DL	2
SET_rotor_ratio	3
SET_rotor_scale	4
SET_rotor_not_radius	5
SET_wing_area	1
MAX_QUANT_rangelowVg	6
MAX_QUANT_range100Vg	7
MAX_QUANT_climb	8
MAX_QUANT_angle	9
MAX_QUANT_power	10
MAX_QUANT_PoV	11
MAX_QUANT_alt	12
MAX_QUANT_Pmargin	13
MAX_QUANT_Qmargin	14
MAX_QUANT_PQmargin	15
MAX_QUANT_Jmargin	16
MAX_QUANT_PJmargin	17
MAX_QUANT_QJmargin	18
MAX_QUANT_PQJmargin	19
MAX_QUANT_Bmargin	20
MAX_QUANT_Lmargin	21
MAX_QUANT_Tmargs	22
MAX_QUANT_Tmargt	23
MAX_QUANT_Tmarge	24
MAX_VAR_none	0
MAX_VAR_vel	-1
MAX_VAR_ROC	-2
MAX_VAR_side	-3
MAX_VAR_alt	-4
MAX_VAR_turn	-5
MAX_VAR_pullup	-6
MAX_VAR_xaccF	-7
MAX_VAR_yaccF	-8
MAX_VAR_zaccF	-9
MAX_VAR_xaccI	-10
MAX_VAR_yaccI	-11
MAX_VAR_zaccI	-12
MAX_VAR_xaccG	-13
MAX_VAR_yaccG	-14
TRIM_QUANT_CXs	29
TRIM_QUANT_XoQ	30
TRIM_QUANT_CTs	31
TRIM_QUANT_Tmargs	32
TRIM_QUANT_Tmargt	33
TRIM_QUANT_Tmarge	34
TRIM_QUANT_rotorP	35
TRIM_QUANT_betac	36
TRIM_QUANT_betas	37
TRIM_QUANT_hubMx	38
TRIM_QUANT_hubMy	39
TRIM_QUANT_hubQ	40
TRIM_QUANT_wingL	41
TRIM_QUANT_wingfL	42
TRIM_QUANT_CL	43
TRIM_QUANT_Lmargin	44
TRIM_QUANT_tailL	45
TRIM_VAR_not_found	0
TRIM_VAR_pitch	-1
TRIM_VAR_roll	-2
TRIM_VAR_ROC	-3
TRIM_VAR_side	-4
TRIM_VAR_speed	-5
TRIM_VAR_turn	-6
TRIM_VAR_pullup	-7
TRIM_VAR_Vtip	-8
TRIM_VAR_Nspec	-9
AERO_VAR_none	0
AERO_VAR_not_found	-1
AERO_VAR_alpha	-2
AERO_VAR_beta	-3
RCCONFIG_rotorcraft	0
RCCONFIG_helicopter	1
RCCONFIG_tandem	2

SET_wing_WL	2
SET_wing_not_area	3
SET_wing_span	4
SET_wing_ratio	5
SET_wing_radius	6
SET_wing_width	7
SET_wing_hub	8
SET_wing_panel	9
SET_wing_not_span	10
SET_tank_input	1
SET_tank_miss	2
SET_tank_fmiss	3
SET_tank_used	4
SET_tank_nopower	0
SET_tank_power	1
SET_SDGW_input	1
SET_SDGW_fDGW	2
SET_SDGW_fWMTO	3
SET_SDGW_maxfuel	4
SET_SDGW_perf	5
SET_WMTO_input	1
SET_WMTO_fDGW	2
SET_WMTO_fSDGW	3
SET_WMTO_maxfuel	4
SET_WMTO_perf	5
SET_limit_input	1
SET_limit_Ratio	2
SET_limit_Pav	3
SET_limit_Preq	4
SET_GW_none	0
SET_GW_DGW	1
SET_GW_SDGW	2
SET_GW_WMTO	3
SET_GW_fDGW	4
MAX_VAR_zaccG	-15
MAX_VAR_pitch	-16
MAX_VAR_roll	-17
MAX_VAR_Vtip	-18
MAX_VAR_Nspec	-19
SET_vel_general	1
SET_vel_hover	2
SET_vel_vert	3
SET_vel_right	4
SET_vel_left	5
SET_vel_rear	6
SET_vel_Vfwd	7
SET_vel_Vmag	8
SET_vel_climb	9
SET_vel_VNE	10
SET_vel_takeoff	11
SET_vel2_TAS	1
SET_vel2_CAS	2
SET_vel2_IAS	3
SET_vel2_Mach	4
SET_atmos_input	-1
SET_atmos_dens	-2
SET_atmos_notair	-3
SET_atmos_std	1
SET_atmos_std_dtemp	2
SET_atmos_std_temp	3
SET_atmos_polar	4
SET_atmos_polar_dtem	5
SET_atmos_polar_temp	6
SET_atmos_trop	7
SET_atmos_trop_dtemp	8
SET_atmos_trop_temp	9
SET_atmos_hot	10
SET_atmos_hot_dtemp	11
RCCONFIG_coaxial	3
RCCONFIG_tiltrotor	4
RCCONFIG_compound	5
RCCONFIG_multicopter	6
RCCONFIG_airplane	7
ROTORCONFIG_main	1
ROTORCONFIG_tail	2
ROTORCONFIG_prop	3
ROTORCONFIG_tandem	4
ROTORCONFIG_coaxial	5
ROTORCONFIG_tiltrotor	6
ROTORCONFIG_not_twin	7
SET_geom_standard	0
SET_geom_tiltrotor	1
SET_geom_coaxial	2
SET_geom_tandem	3
SET_geom_tailrotor	4
SET_geom_multicopter	5
MODEL_twin_none	0
MODEL_twin_sidebyside	1
MODEL_twin_coaxial	2
MODEL_twin_tandem	3
MODEL_twin_multirotor	4
tablevar_none	0
tablevar_V	1
tablevar_Vh	2
tablevar_mu	3
tablevar_muz	4
tablevar_alpha	5
tablevar_muTPP	6
tablevar_muzTPP	7
tablevar_alphaTPP	8
tablevar_CTs	9
tablevar_Mx	10

SET_GW_fSDGW	5
SET_GW_fWMTO	6
SET_GW_input	7
SET_GW_maxP	8
SET_GW_maxQ	9
SET_GW_maxPQ	10
SET_GW_maxJ	11
SET_GW_maxPJ	12
SET_GW_maxQJ	13
SET_GW_maxPQJ	14
SET_GW_source	15
SET_GW_fsource	16
SET_GW_payfuel	17
SET_GW_paymiss	18
SET_UL_pay	1
SET_UL_fuel	2
SET_UL_payfuel	3
SET_UL_miss	4
SET_UL_paymiss	5
SET_pay_none	1
SET_pay_input	2
SET_pay_delta	3
SET_pay_scale	4
KIND_MissSeg_taxi	1
KIND_MissSeg_dist	2
KIND_MissSeg_time	3
KIND_MissSeg_hold	4
KIND_MissSeg_climb	5
KIND_MissSeg_spiral	6
KIND_MissSeg_fuel	7
KIND_MissSeg_burn	8
KIND_MissSeg_takeoff	9
SET_takeoff_none	0
SET_takeoff_start	1
SET_atmos_hot_temp	12
SET_atmos_hot_table	13
SET_Vtip_input	1
SET_Vtip_ref	2
SET_Vtip_speed	3
SET_Vtip_conv	4
SET_Vtip_hover	5
SET_Vtip_cruise	6
SET_Vtip_man	7
SET_Vtip_OEI	8
SET_Vtip_xmsn	9
SET_Vtip_mu	10
SET_Vtip_Mtip	11
SET_Vtip_Mat	12
SET_Vtip_Nrotor	13
STATE_LG_default	0
STATE_LG_extend	1
STATE_LG_retract	2
TRIM_QUANT_not_found	0
TRIM_QUANT_forcex	1
TRIM_QUANT_forcey	2
TRIM_QUANT_forcez	3
TRIM_QUANT_momentx	4
TRIM_QUANT_momenty	5
TRIM_QUANT_momentz	6
TRIM_QUANT_nz	7
TRIM_QUANT_nx	8
TRIM_QUANT_ny	9
TRIM_QUANT_power	10
TRIM_QUANT_Pmargin	11
TRIM_QUANT_Qmargin	12
TRIM_QUANT_powerEG	13
TRIM_QUANT_Emargin	14
TRIM_QUANT_FEmargin	15
tablevar_Mtip	11
tablevar_Mat	12
SET_panel_free	0
SET_panel_span	1
SET_panel_bratio	2
SET_panel_edge	3
SET_panel_station	4
SET_panel_radius	5
SET_panel_width	6
SET_panel_hub	7
SET_panel_adjust	8
SET_panel_area	9
SET_panel_Sratio	10
SET_panel_chord	11
SET_panel_cratio	12
SET_panel_taper	13
SET_tail_area	1
SET_tail_vol	2
SET_tail_span	3
SET_tail_AR	4
SET_tail_chord	5
MODEL_engine_RPTEM	1
MODEL_engine_table	2
MODEL_engine_recip	3
MODEL_engine_comp	4
MODEL_engine_compreact	5
MODEL_engine_compflow	6
MODEL_engine_motor	7
MODEL_engine_gen	8
MODEL_engine_motorgen	9
MODEL_jet_RPJEM	1
MODEL_jet_react	2
MODEL_jet_flow	3
MODEL_jet_simple	4

SET_takeoff_groundrun	2
SET_takeoff_enginefail	3
SET_takeoff_liftoff	4
SET_takeoff_rotation	5

TRIM_QUANT_thrust	16
TRIM_QUANT_Jmargin	17
TRIM_QUANT_FJmargin	18
TRIM_QUANT_charge	19

MODEL_charge_fuelcell	1
MODEL_charge_solarcell	2
MODEL_charge_simple	3

Chapter 4

Common: Job

Variable	Type		Description	Default
			NDARC	
			Version (set by main program)	
version	c*6		number n.n	
modification	c*32		modification	
versionout	c*64		string for headers (`Version n.n, modification "xxx"`)	
		+	Initialization	
INIT_input	int	+	input parameters (0 default, 1 last case input, 2 last case solution)	1
INIT_data	int	+	other parameters (0 default, 1 start of last case, 2 end of last case)	0

INIT_input:
if default, all input variables set to default values
if last-case-input, then case inherits input at beginning of previous case
if last-case-solution, then case inherits input at end of previous case
use INIT_input=2 to analyze case #1 design in subsequent cases
INIT_data: if always start-last-case, then case starts from default
if default, all other variables set to default values

Variable	Type		Description	Default
		+	Errors	
ACT_error	int	+	action on error (0 none, 1 exit)	1
ACT_version	int	+	action on version mismatch in input (0 none, 1 exit)	0
		+	File open	
OPEN_status	int	+	status keyword for write (0 unknown, 1 replace, 2 new, 3 old)	2

		+	Input/output unit numbers	
		+	input	
nuin	int	+	standard input	5
nufile	int	+	secondary file input	40
		+	output	
nuout	int	+	standard output	6
nudesign	int	+	design (DESIGNn)	41
nuperf	int	+	performance (PERFn)	42
nuaero	int	+	airframe aerodynamics (AEROn)	43
nuengine	int	+	engine performance (ENGINEn)	44
nugeom	int	+	geometry output (GEOMETRYn)	45
nuacd	int	+	aircraft description (AIRCRAFTn)	46
nusoln	int	+	solution (SOLUTIONn)	47
nusketch	int	+	sketch output (SKETCHn)	48
nuerror	int	+	errors (ERRORn)	49

---
default input/output unit numbers usually acceptable
default OPEN_status can be changed as appropriate for computer OS

		Analysis
kcase	int	current case number
ncase	int	number of cases (maximum ncasemax)
case_state	int	case state
job_state	int	job state
out_design_state	int	design output state (1 file open)
out_perf_state	int	performance output state (1 file open)
out_geom_state	int	geometry output state (1 file open)
out_error_state	int	errors output state (1 file open)
nuinit	int	nuout or nuerror
fscratch	FltState	scratch structure
		Input
kind_input	int	file input status (0 for primary file, 1 for secondary file, 2 for aircraft or solution file)
nread	int	unit number for input (nuin for primary file, nufile for secondary file)

		Input file identification (stored from action=IDENT data)
ninputfile	int	number of identifications (maximum nfilemax; first is standard input)
input_title(nfilemax)	c*80	title
input_created(nfilemax)	c*20	creation date
theDesign(ncasemax)	Design	Design
theInput	Design	Input
theLastCaseInput	Design	Input from last case

system data = Job + theDesign(ncase) + theInput + theLastCaseInput
all data structure parameters = input (can be changed by analysis) or other (generated by analysis)
theInput used for input (not changed by analysis)
theLastCaseInput used to print only what changed from last case
after case input concluded, kcase incremented and theInput copied to theDesign(kcase)

		CPU time
CPUtime_case_start(ncasemax)	real	case start
CPUtime_case_end(ncasemax)	real	case end
CPUtime_case(ncasemax)	real	case
CPUtime_job	real	job
		Clock time
DateTime_case_start(8,ncasemax)	int	case start
DateTime_case_end(8,ncasemax)	int	case end
ElapsedTime_case(ncasemax)	real	case
ElapsedTime_job	real	job
		Case dimensions
nrotor_case	int	number of rotors (Aircraft)
nwing_case	int	number of wings (Aircraft)
ntail_case	int	number of tails (Aircraft)
ntank_case	int	number of fuel tank systems (Aircraft)

npropulsion_case	int	number of propulsion groups (Aircraft)
nenginegroup_case	int	number of engine groups (Aircraft)
njetgroup_case	int	number of jet groups (Aircraft)
nchargegroup_case	int	number of charge groups (Aircraft)
nenginemodel_case	int	number of engine models (Aircraft)
nengineparamn_case	int	number of engine model parameters (Aircraft)
nenginetable_case	int	number of engine tables (Aircraft)
nrecipmodel_case	int	number of reciprocating engine models (Aircraft)
ncompressormodel_case	int	number of compressor models (Aircraft)
nmotormodel_case	int	number of motor models (Aircraft)
njetmodel_case	int	number of jet models (Aircraft)
nfuelcellmodel_case	int	number of fuel cell models (Aircraft)
nsolarcellmodel_case	int	number of solar cell models (Aircraft)
nbatterymodel_case	int	number of bettery models (Aircraft)
ncontrol_case	int	number of controls (Aircraft)
nstate_control_case	int	number of control states (Aircraft)
npanel_case(nwingmax)	int	number of wing panels (Wing)
mauxtanksize_case(ntankmax)		
	int	number of aux tank sizes (FuelTank)
ngear_case(npropmax)	int	number of drive system states (Propulsion)
nstate_trim_case	int	number of trim states (Aircraft)
mtrim_case(ntrimstatemax)	int	number of trim variables (Aircraft)
nwoful_case	int	number of other fixed useful load categories (System)
		Job constants
pi	real	π
twopi	real	2π
halfpi	real	$\pi/2$
degrad	real	degree/radian = $180/\pi$
raddeg	real	radian/degree = $\pi/180$
		Case constants
gravity	real	gravity g (ft/sec^2 or m/sec^2)
density_sls	real	SLS density ρ_0 (slug/ft^3 or kg/m^3)
csound_sls	real	SLS speed of sound c_s (ft/sec or m/sec)

		Conversion factors
powerconv	real	power (hp from ft-lb/sec; kW from m-N/sec)
knotsconv	real	speed (knots from ft/sec or m/sec)
nmconv	real	range (nm from ft or m)
massconv	real	mass (slug from lb; kg from kg)
volumeconv	real	volume (gal from ft^3; liter from m^3)
		Conversion factors for scaled D/q
DoQconv23	real	$D/q = kW^{2/3}$ (ft^2 from k=$\mathrm{m}^2/\mathrm{kg}^{2/3}$; m^2 from k=$\mathrm{ft}^2/\mathrm{lb}^{2/3}$; depending on Units_Dscale)
DoQconv12	real	$D/q = kW^{1/2}$ (ft^2 from k=$\mathrm{m}^2/\mathrm{kg}^{1/2}$; m^2 from k=$\mathrm{ft}^2/\mathrm{lb}^{1/2}$; depending on Units_Dscale)
		Conversion factors for mission and flight condition input
uconv_vel	real	velocity (knots from input)
uconv_alt	real	altitude (ft or m from input)
uconv_pay	real	payload (lb or kg from input)
uconv_time	real	time (minutes from input)
uconv_dist	real	distance (nm from input)
uconv_drag	real	drag (ft^2 or m^2 from input)
uconv_ROC	real	rate of climb (ft/sec or m/sec from input)
uconv_en	real	Conversion factor for energy (MJ from input)
		Conversion factors for weight equations
wtconv_hp	real	power (hp from hp or kW)
wtconv_lb	real	weight (lb from lb or kg)
wtconv_frc	real	force (lb from lb or N)
wtconv_ft	real	length (ft from ft or m)
wtconv_ft2	real	area (ft^2 from ft^2 or m^2)
wtconv_gal	real	fuel (gal from gal or liter)
wtconv_slug	real	slug (slug/lb or kg/kg)
wtconv_in	real	inches (in/ft or m/m)
wtconv_kW	real	power (kW from hp or kW)
wtconv_m	real	meter (m from ft or m)
		Conversion factors for energy
Econv_kg	real	weight (kg from lb or kg)
Econv_L	real	volume (liter from gal or liter)
Econv_dE	real	energyflow (MJ/hr from hp or kW)

		Conversion factors
DLconv	real	disk loading (lb/ft^2 from lb/ft^2 or N/m^2)
tonconv	real	ton (from lb or kg)
rangeconv	real	range for fuel=1%GW (nm from 1/(lb/hp-hr) or 1/(kg/kW-hr), times $\ln(1/.99)$)
		Output
WRITEenergy_case	int	write fuel energy for burn weight
		Units for output
Uwrite	int	analysis units (from Cases)
Uwrite_temp	int	mission units, temperature (from Cases)
Ukts	c*10	speed (knots, mph, kph, ft/sec, m/sec); uconv_vel
UROC	c*10	rate of climb (ft/min, ft/sec, m/sec); uconv_ROC
Udist	c*10	distance (nm, mile, km); uconv_dist
Utime	c*10	time (min, hr); uconv_time
UDoQ	c*10	drag (ft^2, m^2); uconv_drag
Upay	c*10	payload (lb, kg); uconv_pay
Ualt	c*10	altitude (ft, m); uconv_alt
Ulen	c*10	length
Uarea	c*10	area
Uvol	c*10	volume
Uvel	c*10	velocity
Utemp	c*10	temperature
Uwt	c*10	weight
Upwr	c*10	power
Ufuelflow	c*10	fuel flow
Umassflow	c*10	mass flow
Usfc	c*10	sfc
Utsfc	c*10	thrust sfc
Uspecrange	c*10	specific range
Ufueleff	c*10	fuel efficiency
Uproductivity	c*10	productivity
Ufrc	c*10	force
Umom	c*10	moment
Uque	c*10	dynamic pressure
Udens	c*10	density

Udiskload	c*10	disk loading
Uenergy	c*10	energy
UspecrangeE	c*10	specific range
UfueleffE	c*10	fuel efficiency
UproductivityE	c*10	productivity

Chapter 5

Structure: Design

Variable	Type	Description	Default
Cases	Cases	Cases	
Size	Size	Size Aircraft for Design Conditions and Missions	
OffDesign	OffDesign	Mission Analysis	
Performance	Performance	Flight Performance Analysis	
MapEngine	MapEngine	Map of Engine Performance	
MapAero	MapAero	Map of Airframe Aerodynamics	
Solution	Solution	Solution Procedures	
Cost	Cost	Cost	
Emissions	Emissions	Emissions	
Aircraft	Aircraft	Aircraft	
Systems	Systems	Systems	
Fuselage	Fuselage	Fuselage	
LandingGear	LandingGear	Landing Gear	
Rotor(nrotormax)	Rotor	Rotors	
Wing(nwingmax)	Wing	Wings	
Tail(ntailmax)	Tail	Tails	
FuelTank(ntankmax)	FuelTank	Fuel Tank Systems	
Propulsion(npropmax)	Propulsion	Propulsion Groups	
EngineGroup(nengmax)	EngineGroup	Engine Groups	
JetGroup(njetmax)	JetGroup	Jet Groups	
ChargeGroup(nchrgmax)	ChargeGroup	Charge Groups	
EngineModel(nengmax)	EngineModel	Engine Models	
EngineParamN(nengpmax)	EngineParamN	Engine Model Parameters	
EngineTable(nengmax)	EngineTable	Engine Tables	
RecipModel(nengmax)	RecipModel	Reciprocating Engine Models	
CompressorModel(nengmax)	CompressorModel	Compressor Models	
MotorModel(nengmax)	MotorModel	Motor Models	
JetModel(njetmax)	JetModel	Jet Models	

FuelCellModel(nchrgmax)	FuelCellModel	Fuel Cell Models
SolarCellModel(nchrgmax)	SolarCellModel	Solar Cell Models
BatteryModel(ntankmax)	BatteryModel	Battery Models

Chapter 6

Structure: Cases

Variable	Type		Description	Default
		+	Case Description	
title	c*100	+	title	
subtitle1	c*100	+	subtitle	
subtitle2	c*100	+	subtitle	
subtitle3	c*100	+	subtitle	
notes	c*1000	+	notes	
ident	c*32	+	identification	
timedate	c*20		time-date identification	
		+	Case Tasks (0 for none)	
TASK_Size	int	+	size aircraft for design conditions	1
TASK_Mission	int	+	mission analysis	1
TASK_Perf	int	+	flight performance analysis	1
TASK_Map_engine	int	+	map of engine performance	0
TASK_Map_aero	int	+	map of airframe aerodynamics	0

Turn off all tasks to just initialize and check the model, including geometry and weights

Variable	Type		Description	Default
		+	Write Input Parameters	
WRITE_input	int	+	selection (0 none, 1 all, 2 first case)	2
WRITE_input_TechFactors	int	+	TechFactors (0 for none)	1
WRITE_input_Geometry	int	+	Geometry (0 for none)	1

		+	Output	
		+	selection (0 for none)	
OUT_design	int	+	design file	0
OUT_perf	int	+	performance file	0
OUT_geometry	int	+	geometry file	0
OUT_aircraft	int	+	aircraft description file	0
OUT_solution	int	+	solution file (1 text, 2 binary)	0
OUT_sketch	int	+	sketch file	0
OUT_error	int	+	errors file	0
		+	file name or logical name (blank for default logical name)	
FILE_design	c*256	+	design file (DESIGNn)	' '
FILE_perf	c*256	+	performance file (PERFn)	' '
FILE_geometry	c*256	+	geometry file (GEOMETRYn)	' '
FILE_aircraft	c*256	+	aircraft description file (AIRCRAFTn)	' '
FILE_solution	c*256	+	solution file (SOLUTIONn)	' '
FILE_sketch	c*256	+	sketch file (SKETCHn)	' '
FILE_engine	c*256	+	engine performance file (ENGINEn)	' '
FILE_aero	c*256	+	airframe aerodynamics file (AEROn)	' '
FILE_error	c*256	+	errors file (ERRORn)	' '
		+	formats	
WRITE_page	int	+	page control (0 none, 1 form feed, 2 extended Fortran)	1
WRITE_design	int	+	design (1 first case only, 2 all cases)	2
WRITE_wt_level	int	+	weight statement, max level (1 to 5)	5
WRITE_wt_long	int	+	weight statement, style (0 omit zero lines, 1 all lines)	0
WRITE_energy	int	+	fuel energy for burn weight (0 for none)	1
WRITE_flight	int	+	flight state, component loads (0 for none)	0
WRITE_files	int	+	design, performance, or geometry (1 single file of all cases)	0
WRITE_sketch_load	int	+	sketch component forces (0 none)	1
WRITE_sketch_cond	int	+	sketch flight condition (0 none, 1 design, 2 performance)	0
ksketch	int	+	flight condition number	0

---

selected files are generated for each case (n = case number in default name)
option single file of all cases for design, performance, or geometry (form feed between cases)

size and analysis tasks can produce design and performance files
same information as in standard output, in tab-delimited form
aircraft or solution file can be read by subsequent case or job
geometry file has information for graphics and other analyses
sketch file has information to check geometry and solution (DXF format)
flight condition required to use Euler angles, control and incidence, component forces
engine map task (TASK_Map_engine) produces engine performance file
airframe aerodynamics map task (TASK_Map_aero) produces airframe aerodynamics file
error messages to standard output (OUT_error=0) or separate file (OUT_error=1)

		+	Gravity	
SET_grav	int	+	specification (0 standard, 1 input)	0
grav	real	+	input gravitational acceleration g	
		+	Environment	
density_ref	real	+	reference density (0. for air at SLS)	0.
csound_ref	real	+	reference speed of sound (0. for air at SLS)	0.
		+	Units	
Units	int	+	analysis units (1 English, 2 SI)	1
		+	units for input of missions and flight conditions	
Units_miss	int	+	override default units (0 no, 1 yes)	0
Units_vel	int	+	velocity units (0 knots; 1 mile/hr, 2 km/hr, 3 ft/sec, 4 m/sec)	0
Units_alt	int	+	altitude units (0 ft or m; 1 ft, 2 m)	0
Units_pay	int	+	payload units (0 lb or kg; 1 lb, 2 kg)	0
Units_time	int	+	time units (0 minutes; 1 hours)	0
Units_dist	int	+	distance units (0 nm; 1 miles; 2 km)	0
Units_temp	int	+	temperature (0 F or C; 1 F, 2 C)	0
Units_drag	int	+	drag units (0 ft^2 or m^2; 1 ft^2, 2 m^2)	0
Units_ROC	int	+	rate of climb units (0 ft/min; 1 ft/sec, 2 m/sec)	0
		+	units for parameters	
Units_Dscale	int	+	input D/q scaled with gross weight (0 analysis default, 1 English, 2 SI)	0
Units_energy	int	+	units for energy input and output (1 MJ, 2 kWh)	1

Analysis units: must be same for all cases in job
  English: ft-slug-sec-F; weights in lb, power in hp (internal units)
  SI: m-kg-sec-C; weights in kg, power in kW (internal units)
Weight in the design description is actually mass
  pounds converted to slugs using reference gravitational acceleration
Default units for flight condition and mission: override with Units_xxx
  speed in knots, time in minutes, distance in nm, ROC in ft/min
Input Efuel_cap, Eaux_cap always MJ; internal energy units MJ

		Input for case
inCases	int	Cases
inSize	int	Size
inSizeCondition(nfltmax)	int	SizeCondition
inSizeMission(nmissmax)	int	SizeMission
inOffDesign	int	OffDesign
inOffMission(nmissmax)	int	OffMission
inPerformance	int	Performance
inPerfCondition(nfltmax)	int	PerfCondition
inMapEngine	int	MapEngine
inMapAero	int	MapAero
inSolution	int	Solution
		Last input
lastSizeCondition	int	SizeCondition
lastSizeMission	int	SizeMission
lastOffMission	int	OffMission
lastPerfCondition	int	PerfCondition

---

case input of other structures recorded in Aircraft structure
there must be input for systems, fuselage, landing gear, fuel tank
there must be input for all structures used

Chapter 7

Structure: Size

Variable	Type	Description	Default
		Size Aircraft for Design Conditions and Missions	
SizeParam	SizeParam	Parameters	
		Sizing Flight Conditions	
FltCond(nfltmax)	FltCond	conditions	
FltState(nfltmax)	FltState	conditions	
		Design Missions	
Mission(nmissmax)	Mission	missions	

Chapter 8

Structure: SizeParam

Variable	Type		Description	Default
		+	Size Aircraft for Design Conditions and Missions	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Sizing Method	
SIZE_perf(npropmax)	c*16	+	quantity sized from performance	'engine'
SIZE_engine(nengmax)	c*16	+	engine group sized from performance	'none'
SIZE_jet(njetmax)	c*16	+	jet group sized from performance	'jet'
SIZE_charge(nchrgmax)	c*16	+	charge group sized from performance	'none'
SIZE_param	int	+	parameter iteration (0 not required)	0
SET_rotor(nrotormax)	c*32	+	rotor parameters	'DL+Vtip+CWs'
SET_wing(nwingmax)	c*16	+	wing parameters	'WL+aspect'
FIX_DGW	int	+	design gross weight (0 calculated, 1 fixed)	0
FIX_WE	int	+	weight empty (0 calculated, 1 fixed, 2 scaled)	0
SET_tank(ntankmax)	c*16	+	fuel tank capacity	'miss'
SET_SDGW	c*16	+	structural design gross weight	'f(DGW)'
SET_WMTO	c*16	+	maximum takeoff weight	'f(DGW)'
SET_limit_ds(npropmax)	c*16	+	drive system torque limit	'ratio'

size task (Cases%TASK_Size=1): at least one nFltCond or nMission
no size task (Cases%TASK_Size=0): size input specifies how fixed aircraft determined

SIZE_perf: size power-producing engines of propulsion group
  'engine' = power from maximum of power required for all designated conditions and missions
  'rotor' = radius from maximum of power required for all designated conditions and missions
  'none' = power required not used to size engine/rotor
    flight conditions and missions (max GW, max effort, or trim)
      that have zero power margin are not used to size engine or rotor
      that have zero torque margin are not used to size transmission

SIZE_engine: size power-consuming engines of engine group
'engine' = power from maximum of power required for all designated conditions and missions
flight conditions and missions (max GW, max effort, or trim)
that have zero power margin are not used to size engine group
designated only for engine groups that consume power
engine groups that produce power sized with propulsion group (SIZE_perf)
'none' = power required not used to size engine group
SIZE_jet:
'jet' = thrust from maximum of thrust required for all designated conditions and missions
'none' = thrust required not used to size jet group
flight conditions and missions (max GW, max effort, or trim)
that have zero thrust margin are not used to size jet group
SIZE_charge:
'charge' = power from maximum of power required for all designated conditions and missions
'none' = power required not used to size charge group
'SIZE_param': use to force parameter iteration

SET_rotor, rotor parameters: required for each rotor
rotor parameters: input three or two quantities, others derived
SET_rotor = input three of ('radius' or disk loading 'DL' or 'ratio'), 'CWs', 'Vtip', 'sigma'
except if SIZE_perf='rotor': SET_rotor = input two of 'CWs', 'Vtip', 'sigma' for one or more main rotors
SET_rotor = 'ratio+XX+XX' to calculate radius from radius of another rotor
tip speed is Vtip_ref for drive state #1
rotor parameters for an antitorque or aux thrust rotor:
SET_rotor = input three of ('radius' or 'DL' or 'ratio' or 'scale'), 'CWs', 'Vtip', 'sigma'
SET_rotor = 'scale+XX+XX' to calculate tail rotor radius from parametric equation,
using main rotor radius and disk loading
thrust from designated sizing conditions and missions (DESIGN_thrust)

SET_wing, wing parameters: for each wing; input two quantities, other two derived
SET_wing = input two of ('area' or wing loading 'WL'), ('span' or 'ratio' or 'radius'or 'width' or 'hub' or 'panel'),
'chord', aspect ratio 'aspect'
SET_wing = 'ratio+XX' to calculate span from span of another wing
SET_wing = 'radius+XX' to calculate span from rotor radius
SET_wing = 'width+XX' to calculate span from rotor radius, fuselage width, and clearance (tiltrotor)

SET_wing = 'hub+XX' to calculate span from rotor hub position (tiltrotor)
SET_wing = 'panel+XX' to calculate span from wing panel widths

FIX_DGW: input DGW restricts SIZE_perf, SET_GW parameters
FIX_WE: fixed or scaled weight empty obtained by adjusting contingency weight
scaled with design gross weight: W_E=dWE+fWE*W_D

SET_tank, fuel tank sizing: usable fuel capacity Wfuel_cap (weight) or Efuel_cap (energy)
'input' = input Wfuel_cap or Efuel_cap
'miss' = calculate from mission fuel used
Wfuel_cap or Efuel_cap = max(fFuel_cap*(maximum mission fuel), (maximum mission fuel)+(reserve fuel))
'f(miss)' = function of mission fuel used
Wfuel_cap or Efuel_cap = dFuel_cap + fFuel_cap*((maximum mission fuel)+(reserve fuel))
'used' = calculate from maximum fuel quantity in tank during mission
Wfuel_cap or Efuel_cap = dFuel_cap + fFuel_cap*(maximum fuel in tank)
'XX+power' = and calculate from mission battery discharge power

SET_SDGW, structural design gross weight:
'input' = input
'f(DGW)' = based on DGW; W_{SD}=dSDGW+fSDGW*W_D
'f(WMTO)' = based on WMTO; W_{SD}=dSDGW+fSDGW*W_{MTO}
'maxfuel' = based on fuel state; W_{SD}=dSDGW+fSDGW*W_G, $W_G = W_D$–Wfuel_DGW+fFuelSDGW*$W_{\text{fuel-cap}}$
'perf' = calculated from maximum gross weight at SDGW sizing conditions (DESIGN_sdgw)
Aircraft input parameters: dSDGW, fSDGW, fFuelSDGW
SET_WMTO, maximum takeoff weight:
'input' = input
'f(DGW)' = based on DGW; W_{MTO}=dWMTO+fWMTO*W_D
'f(SDGW)' = based on SDGW; W_{MTO}=dWMTO+fWMTO*W_{SD}
'maxfuel' = based on maximum fuel; W_{MTO}=dWMTO+fWMTO*W_G, $W_G = W_D$–Wfuel_DGW+$W_{\text{fuel-cap}}$
'perf' = calculated from maximum gross weight at WMTO sizing conditions (DESIGN_wmto)
Aircraft input parameters: dWMTO, fWMTO

SET_limit_ds, drive system torque limit: input (use Plimit_xx) or calculate (from fPlimit_xx)
'input' = Plimit_ds input
'ratio' = from takeoff power, fPlimit_ds$\sum(N_{\rm eng}P_{\rm eng})$
'Pav' = from engine power available at transmission sizing conditions and missions (DESIGN_xmsn)
fPlimit_ds$(\Omega_{\rm ref}/\Omega_{\rm prim})\sum(N_{\rm eng}P_{av})$
'Preq' = from engine power required at transmission sizing conditions and missions (DESIGN_xmsn)
fPlimit_ds$(\Omega_{\rm ref}/\Omega_{\rm prim})\sum(N_{\rm eng}P_{req})$
engine shaft limit also uses EngineGroup%SET_limit_es
rotor shaft limit also uses Rotor%SET_limit_rs, rotor limits only use power required (or input)

input required to transmit sized rotorcraft to another job (through aircraft description file) or to following case:
turn off sizing: Cases%TASK_size=0, Cases%TASK_mission=1, Cases%TASK_perf=1
fix aircraft: use ACTION='nosize', or
SIZE_perf='none', SIZE_engine='none', SIZE_jet='none', SIZE_charge='none'
SET_rotor='radius+Vtip+sigma', SET_wing='area+span', FIX_DGW=1
SET_tank='input', SET_limit_ds='input', SET_SDGW='input', SET_WMTO='input'
with wing panels: SET_wing='WL+panel', Wing%SET_panel='width+taper','span+taper'

		Specification
iSIZE_perf(npropmax)	int	performance (SIZE_perf_engine, rotor, none)
iSIZE_engine(nengmax)	int	performance (SIZE_engine_engn, none)
iSIZE_jet(njetmax)	int	performance (SIZE_jet_jet, none)
iSIZE_charge(nchrgmax)	int	performance (SIZE_charge_chrg, none)
iSIZE_rotor(nrotormax)	int	rotor sized (SIZE_rotor_radius, thrust, none)
iSET_rotor_radius(nrotormax)	int	rotor radius (SET_rotor_radius, DL, ratio, scale, not_radius)
FIX_rotor_CWs(nrotormax)	int	rotor C_W/σ (1 fixed, 0 not)
FIX_rotor_Vtip(nrotormax)	int	rotor $V_{\rm tip}$ (1 fixed, 0 not)
FIX_rotor_sigma(nrotormax)	int	rotor σ (1 fixed, 0 not)
iSET_wing_area(nwingmax)	int	wing area (SET_wing_area, WL, not_area)
iSET_wing_span(nwingmax)	int	wing span (SET_wing_span, ratio, radius, width, hub, panel, not_span)
FIX_wing_chord(nwingmax)	int	wing chord (1 fixed, 0 not)

FIX_wing_AR(nwingmax)	int	wing aspect ratio (1 fixed, 0 not)
iSET_tank(ntankmax)	int	fuel tank (SET_tank_input, miss, fmiss, used)
iSET_tank_power(ntankmax)	int	fuel tank (SET_tank_nopower, power)
iSET_SDGW	int	SDGW (SET_SDGW_input, fDGW, fWMTO, maxfuel, perf)
iSET_WMTO	int	WMTO (SET_WMTO_input, fDGW, fSDGW, maxfuel, perf)
iSET_limit_ds(npropmax)	int	drive system torque limit (SET_limit_input, ratio, Pav, Preq)
		Number of conditions and missions
nSIZE_perf(npropmax)	int	conditions and missions for size engine or rotor
nSIZE_engine(nengmax)	int	conditions and missions for size engine group
nSIZE_jet(njetmax)	int	conditions and missions for size jet group
nSIZE_charge(nchrgmax)	int	conditions and missions for size charge group
nDESIGN_GW	int	design conditions and missions for DGW
nDESIGN_xmsn(npropmax)	int	design conditions and missions for transmission
nDESIGN_sdgw	int	design conditions for SDGW
nDESIGN_wmto	int	design conditions for WMTO
nDESIGN_tank	int	design missions for fuel tank
nDESIGN_thrust	int	design conditions and missions for rotor thrust
		Size aircraft
kind_iter_size	int	kind iteration, performance (0 none, 1 size engine or radius, or engine group, or jet group, or charge group)
kind_iter_param	int	kind iteration, parameters (0 none, 1 calculate parameters)
issizeconv	int	converged (0 not)
count_size	int	number of iterations, performance loop
count_param	int	number of iterations, parameter loop
count_total	int	total number of iterations
		error ratio
error_engine(nengmax)	real	engine
error_jet(njetmax)	real	jet
error_charge(nchrgmax)	real	charge
error_rotor(nrotormax)	real	rotor
error_DGW	real	DGW
error_xmsn(npropmax)	real	Plimit
error_sdgw	real	structural design gross weight
error_wmto	real	maximum takeoff weight
error_tank	real	Wfuelcap (rms all tanks)

error_thrust(nrotormax)	real		thrust	
error_WE	real		WE	
			residual (difference after one size iteration)	
resid_engine(nengmax)	real		engine power Peng = $P_{\rm eng}$	
resid_jet(njetmax)	real		jet thrust Tjet = $T_{\rm jet}$	
resid_charge(nchrgmax)	real		charge power Pchrg = $P_{\rm chrg}$	
resid_rotor(nrotormax)	real		rotor radius R	
resid_DGW	real		design gross weight DGW	
resid_xmsn(npropmax)	real		transmission limit Plimit_ds = $P_{DS{\rm limit}}$	
resid_sdgw	real		structural design gross weight SDGW	
resid_wmto	real		maximum takeoff weight WMTO	
resid_tank(ntankmax)	real		fuel capacity Wfuel_cap = $W_{\rm fuel-cap}$ or Efuel_cap = $E_{\rm fuel-cap}$	
resid_thrust(nrotormax)	real		rotor design thrust Tdesign	
resid_WE	real		weight empty WE	
Pratio(npropmax)	real		ratio P_{reqPG}/P_{avPG} (max all sizing conditions and missions)	
Eratio(nengmax)	real		ratio P_{reqEG}/P_{avEG} (max all sizing conditions and missions)	
Jratio(njetmax)	real		ratio T_{reqJG}/T_{avJG} (max all sizing conditions and missions)	
Cratio(nchrgmax)	real		ratio P_{reqCG}/P_{avCG} (max all sizing conditions and missions)	
nFltCond_out	int		number of conditions for output	
nMission_out	int		number of missions for output	
		+	Sizing Flight Conditions	
nFltCond	int	+	number of conditions (maximum nfltmax)	0
		+	Design Missions	
nMission	int	+	number of missions (maximum nmissmax)	0

---

input one condition (FltCond and FltState variables) in SizeCondition namelist

input one mission (MissParam, MissSeg, and FltState variables) in SizeMission namelist
all mission segments are defined in this namelist, so MissSeg and FltState variables are arrays
each variable gets one more dimension, first array index is always segment number

---

Chapter 9

Structure: OffDesign

Variable	Type	Description	Default
		Mission Analysis	
OffParam	OffParam	Parameters	
Mission(nmissmax)	Mission	Missions	

Chapter 10

Structure: OffParam

Variable	Type		Description	Default
		+	Mission Analysis	
title	c*100	+	title	
notes	c*1000	+	notes	
			Analyze mission	
nMission_out	int		number of missions for output	
		+	Missions	
nMission	int	+	number of missions (maximum nmissmax)	0

mission analysis input required if Cases%TASK_Mission=1

input one mission (MissParam, MissSeg, and FltState variables) in OffMission namelist
all mission segments are defined in this namelist, so MissSeg and FltState variables are arrays
each variable gets one more dimension, first array index is always segment number

Chapter 11

Structure: Performance

Variable	Type	Description	Default
		Flight Performance Analysis	
PerfParam	PerfParam	Parameters	
		Performance Flight Conditions	
FltCond(nfltmax)	FltCond	conditions	
FltState(nfltmax)	FltState	conditions	

Chapter 12

Structure: PerfParam

Variable	Type		Description	Default
		+	Flight Performance Analysis	
title	c*100	+	title	
notes	c*1000	+	notes	
			Analyze performance	
nFltCond_out	int		number of conditions for output (including sweeps)	
nsweep_total	int		total number of sweep conditions	
		+	Performance Flight Conditions	
nFltCond	int	+	number of conditions (maximum nfltmax)	0

flight performance analysis input required if Cases%TASK_Perf=1

input one condition (FltCond and FltState variables) in PerfCondition namelist

Chapter 13

Structure: MapEngine

Variable	Type		Description	Default
		+	Map of Engine Performance	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Identification	
kEngineGroup	int	+	engine group	1
KIND_map	int	+	Kind (1 performance, 2 model)	1

engine map only available for RPTEM model and reciprocating engine model (performance only)

engine map input required if Cases%TASK_Map_engine=1
only performance parameters or only model parameters used

Variable	Type		Description	Default
		+	Performance	
		+	independent variables (0 none, 1 altitude, 2 temperature, 3 flight speed, 4 engine speed, 5 power)	
SET_var(5)	int	+	first set	0
SET_var2(5)	int	+	second set	0
WRITE_header	int	+	output format (1 single header, 2 header for inner variable)	2
SET_atmos	c*12	+	atmosphere specification	'std'
		+	altitude h (Units_alt)	
altitude_min	real	+	minimum	0.
altitude_max	real	+	maximum	20000.
altitude_inc	real	+	increment	1000.
altitude_base	real	+	baseline	0.

		+	temperature τ or temperature increment ΔT (Units_temp)	
temp_min	real	+	minimum	0.
temp_max	real	+	maximum	100.
temp_inc	real	+	increment	10.
temp_base	real	+	baseline	0.
		+	flight speed V (TAS, Units_vel)	
Vkts_min	real	+	minimum	0.
Vkts_max	real	+	maximum	200.
Vkts_inc	real	+	increment	50.
Vkts_base	real	+	baseline	0.
SET_rpm	int	+	engine speed N (1 rpm, 2 percent)	2
Nturbine_min	real	+	minimum	90.
Nturbine_max	real	+	maximum	110.
Nturbine_inc	real	+	increment	5.
Nturbine_base	real	+	baseline	100.
SET_power	int	+	power required (1 power, 2 fraction of power available (0. to 1.+)	2
power_min	real	+	minimum	.1
power_max	real	+	maximum	1.
power_inc	real	+	increment	.1
power_base	real	+	baseline	1.
STATE_IRS	int	+	IR suppressor system state (0 off, hot exhaust; 1 on, suppressed exhaust)	0
KIND_loss	int	+	installation losses (0 for none)	0

---

independent variables: 1 to 5 variables, last is innermost loop; outer loop is always rating
quantities not identified as independent variables fixed at baseline values

SET_atmos, atmosphere specification:
determines whether temp_xxx is temperature or temperature increment
'std' = standard day at specified altitude (use altitude_xxx)
'temp' = standard day at specified altitude, and specified temperature (use altitude_xxx, temp_xxx)
'dtemp' = standard day at specified altitude, plus temperature increment (use altitude_xxx, temp_xxx)
see FltState%SET_atmos for other options (polar, tropical, and hot days)

		+	Model	
		+	flight speeds V (TAS, Units_vel)	
nV_model	int	+	number (maximum 10)	1
V_model(10)	real	+	values	0.
V_min	real	+	minimum	0.
V_max	real	+	maximum	400.
V_inc	real	+	increment	50.
		+	temperature ratio T/T_0	
ntheta_model	int	+	number (maximum 10)	1
theta_model(10)	real	+	values	1.
theta_min	real	+	minimum	.8
theta_max	real	+	maximum	1.1
theta_inc	real	+	increment	.02
		+	engine speed, N/N_{spec} (percent)	
fN_min	real	+	minimum	90.
fN_max	real	+	maximum	110.
fN_inc	real	+	increment	5.
		+	fraction static MCP power, P/P_{0C}	
fP_min	real	+	minimum	.1
fP_max	real	+	maximum	2.
fP_inc	real	+	increment	.1

RPTEM model
- performance: fuel flow, mass flow, net jet thrust, optimum turbine speed
  - vs power fraction and airspeed (use fP and V_model)
- turbine speed: power ratio vs turbine speed and airspeed (use fN and V_model)
- power available: specific power, mass flow, power, fuel flow
  - vs temperature ratio (use theta and V_model)
  - vs airspeed (use V and theta_model)

		Specification
kEngineModel	int	engine model
iSET_atmos	int	atmosphere (SET_atmos_xxx)
nSET_var	int	number of independent variable sets

Chapter 14

Structure: MapAero

Variable	Type		Description	Default
		+	Map of Airframe Aerodynamics	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Tables	
KIND_table	int	+	kind (1 one-dimensional, 2 multi-dimensional)	1
		+	aerodynamic loads (0 for components off)	
SET_fuselage	int	+	fuselage and landing gear	1
SET_tail	int	+	tails	1
SET_wing	int	+	wings	1
SET_rotor	int	+	rotors	1
SET_engine	int	+	engines and fuel tank	1

airframe aerodynamics map input required if Cases%TASK_Map_aero=1

multi-dimensional: generate 6 files of three-dimensional tables
one file for each `load=DRAG, SIDE, LIFT, ROLL, PITCH, YAW`
filename=`FILE_aero//load` or `AEROn//load`
one-dimensional: generate 1 file of all six loads
function of single independent variable = var_lift(1)

Variable	Type		Description	Default
		+	Operating Condition	
STATE_control	int	+	aircraft control state	1
STATE_LG	c*12	+	landing gear state	'retract'
Nauxtank(nauxtankmax,ntankmax)	int	+	number of auxiliary fuel tanks N_{auxtank} (each aux tank size)	0

SET_extkit	int	+	wing extension kit on aircraft (0 none, 1 present)	1
KIND_alpha	int	+	angle of attack and sideslip angle representation (1 conventional, 2 reversed)	1
SET_comp_control	int	+	use component control (0 for $c = Tc_{AC}$; 1 for $c = Tc_{AC} + c_0$)	0
control(ncontmax)	real	+	aircraft controls	0.
tilt	real	+	tilt	0.
alpha	real	+	angle of attack α	0.
beta	real	+	sideslip angle β	0.

landing gear state: STATE_LG='extend', 'retract' (keyword = ext, ret)

		+	Independent variables	
var_lift(3)	c*16	+	lift	
var_drag(3)	c*16	+	drag	
var_side(3)	c*16	+	side force	
var_pitch(3)	c*16	+	pitch moment	
var_roll(3)	c*16	+	roll moment	
var_yaw(3)	c*16	+	yaw moment	
		+	Variable range	
		+	angle of attack and sideslip variation	
angle_lowinc	real	+	low range increment (deg)	2.
angle_highinc	real	+	high range increment (deg)	5.
angle_low	real	+	low range value (deg)	40.
angle_max	real	+	maximum value (deg)	180.
		+	control variation	
control_lowinc	real	+	low range increment (deg)	2.
control_highinc	real	+	high range increment (deg)	2.
control_low	real	+	low range value (deg)	45.
control_max	real	+	maximum value (deg)	90.
		+	third independent variable	
gamma_lowinc	real	+	low range increment (deg)	20.
gamma_highinc	real	+	high range increment (deg)	20.
gamma_low	real	+	low range value (deg)	60.
gamma_max	real	+	maximum value (deg)	60.

var_load identify independent variables
only var_lift(1) used for KIND_table=one-dimensional
values: 'alpha', 'beta', IDENT_control(ncontrol)
var_load(2) blank for 1D table, var_load(3) blank for 2D table
alpha/beta/controls/tilt fixed if not independent variable (tilt replace control(ktilt))
assume control system defined so aircraft controls connected to flaperon, elevator, aileron, rudder

angle, control, gamma variation: by lowinc for -low to +low; by highinc to -max and +max
maximum total values = naeromax

		Operating Condition
iSTATE_LG	int	landing gear state (STATE_LG_extend, retract)
		Independent variables (AERO_VAR_none, alpha, beta, or control number)
nvar(6)	int	number of independent variables
ivar(3,6)	int	variables (drag, side, lift, roll, pitch, yaw)
		Tables
nang	int	number of angles (maximum naeromax)
ang(naeromax)	real	angle values
ncnt	int	number of controls (maximum naeromax)
cnt(naeromax)	real	control values
ngam	int	number of gamma (maximum naeromax)
gam(naeromax)	real	gamma values

Structure: FltCond

Variable	Type		Description	Default
		+	Sizing or Performance Flight Condition	
title	c*100	+	title	
label	c*8	+	label	
		+	Specification	
SET_GW	c*12	+	gross weight	'DGW'
GW	real	+	input gross weight W_G	0.
dGW	real	+	gross weight increment	0.
fGW	real	+	gross weight factor	1.
dPav(npropmax)	real	+	power increment, each propulsion group	0.
fPav(npropmax)	real	+	power factor, each propulsion group	1.
dTav(njetmax)	real	+	thrust increment, each jet group	0.
fTav(njetmax)	real	+	thrust factor, each jet group	1.
SET_Wlimit	c*12	+	gross weight limit	'none'
Wlimit	real	+	input gross weight limit	0.
SET_alt	int	+	altitude (0 input, 1 from KIND_source)	0
		+	source for gross weight and altitude	
KIND_source	int	+	kind (1 size mission, 2 size condition, 3 off design mission, 4 performance condition)	1
kSource	int	+	mission or condition number	0
kSegment	int	+	segment number	0
seg_source	int	+	segment (1 start, 2 midpoint)	1
SET_UL	c*12	+	useful load	'pay'
Wpay	real	+	input payload weight $W_{\rm pay}$ (Units_pay)	0.
Npass	int	+	number of passengers $N_{\rm pass}$	0
Wpay_cargo	real	+	cargo $W_{\rm cargo}$ (Units_pay)	0.
Wpay_extload	real	+	external load $W_{\rm ext-load}$ (Units_pay)	0.
Wpay_ammo	real	+	ammunition $W_{\rm ammo}$ (Units_pay)	0.
Wpay_weapons	real	+	weapons $W_{\rm weapons}$ (Units_pay)	0.

		+	fuel tank system	
dFuel(ntankmax)	real	+	fuel weight or energy increment	0.
fFuel(ntankmax)	real	+	fuel capacity factor	1.
SET_auxtank(ntankmax)	int	+	auxiliary fuel tanks (1 adjust Nauxtank, 2 only increase, 0 no change)	1
mauxtank(ntankmax)	int	+	tank size changed (–1 first, –2 first size already used, m for m-th size)	-1
dNauxtank(ntankmax)	int	+	number tanks added or dropped	1
Nauxtank(nauxtankmax,ntankmax)				
	int	+	number of auxiliary fuel tanks $N_{\rm auxtank}$ (each aux tank size)	
		+	fixed useful load	
dWcrew	real	+	crew weight increment	0.
dNcrew	int	+	number of crew increment $\delta N_{\rm crew}$	0
dWoful(10)	real	+	other fixed useful load increment (nWoful categories)	0.
dWequip	real	+	equipment weight increment	0.
dNcrew_seat	int	+	crew seat increment $\delta N_{\rm crew-seat}$	0
dNpass_seat	int	+	passenger seat increment $\delta N_{\rm pass-seat}$	0
		+	kits on aircraft (0 none, 1 present)	
SET_foldkit	int	+	folding kit	1
SET_extkit(nwingmax)	int	+	wing extension kit	1
SET_wingkit(nwingmax)	int	+	wing kit on aircraft	1
SET_otherkit	int	+	other kit on aircraft	0
DESIGN_engine	int	+	design condition for power (1 to use for engine sizing)	1
DESIGN_jet	int	+	design condition for jet thrust (1 to use for jet group sizing)	1
DESIGN_charge	int	+	design condition for charge power (1 to use for charge group sizing)	1
DESIGN_GW	int	+	design condition for DGW (1 to use for DGW calculation)	1
DESIGN_xmsn	int	+	design condition for transmission (1 to use for transmission sizing)	1
DESIGN_sdgw	int	+	design condition for SDGW (1 to use for SDGW calculation)	1
DESIGN_wmto	int	+	design condition for WMTO (1 to use for WMTO calculation)	1
DESIGN_thrust	int	+	design condition for antitorque or aux thrust (1 to use for rotor sizing)	1

---

label is short description for output

sizing flight condition: use all parameters except sweep

fixed gross weight conditions not used to determine DGW, SDGW, WMTO

(set DESIGN_GW=0, DESIGN_sdgw=0, DESIGN_wmto=0)

condition not used to size engine or rotor if power margin fixed (max GW, max effort, or trim)

condition not used to size transmission if zero torque margin (max GW, max effort, or trim)

performance flight condition: not use DESIGN_xx
SET_GW, SET_UL values determine which input parameters used

SET_GW, set gross weight W_G:
- 'DGW' = design gross weight W_D; input (FIX_DGW) or calculated
- 'SDGW' = structural design gross weight W_{SD} (may depend on DGW)
- 'WMTO' = maximum takeoff gross weight W_{MTO} (may depend on DGW)
- 'f(DGW)' = function DGW: fGW*W_D+dGW
- 'f(SDGW)' = function SDGW: fGW*W_{SD}+dGW
- 'f(WMTO)' = function WMTO: fGW*W_{MTO}+dGW
- 'input' = input (use GW)
- 'source' = gross weight from specified mission segment or flight condition (KIND_source)
- 'f(source)' = function of source: fGW*W_{source}+dGW
- 'maxP', 'max' = maximum GW for power required equal specified power: P_{req} = fPavP_{av} + dPav
  $\min((fP_{avPG} + d) - P_{reqPG}) = 0$, over all propulsion groups
- 'maxQ' = maximum GW for transmission torque equal limit: zero torque margin
  $\min(P_{\text{limit}} - P_{req}) = 0$, over all propulsion groups, engine groups, and rotors
- 'maxPQ', 'maxQP' = maximum GW for power required equal specified power and transmission torque equal limit
  most restrictive of power and torque margins
- 'maxJ' = maximum GW for jet thrust required equal specified thrust: T_{req} = fTavT_{av} + dTav
  $\min((fT_{avJG} + d) - T_{reqJG}) = 0$, over all jet groups
- 'maxPJ', 'maxQJ', 'maxPQJ' = maximum GW for most restrictive of power, torque, and thrust margins
- 'pay+fuel' = input payload and fuel weights; gross weight fallout

SET_Wlimit: weight limit for SET_GW='max'
- 'none' = no limit
- 'f(DGW)' = function DGW: fGW*W_D+dGW
- 'f(SDGW)' = function SDGW: fGW*W_{SD}+dGW
- 'f(WMTO)' = function WMTO: fGW*W_{MTO}+dGW
- 'input' = input (use Wlimit)

SET_UL, set useful load: with fixed useful load adjustments in fallout weight
- 'pay' = input payload weight (Wpay); fuel weight fallout
- 'fuel' = input fuel weight (dFuel, fFuel, Nauxtank); payload weight fallout
- 'pay+fuel' = input payload and fuel weights; gross weight fallout

if SET_GW='pay+fuel', assume SET_UL same (actual SET_UL ignored)

KIND_source, source for gross weight or altitude: source must be solved before this condition
calculation order: size missions, size conditions, off design missions, performance conditions

input fuel weight: $W_{\text{fuel}} = \min(\text{dFuel}+\text{fFuel}*W_{\text{fuel-cap}}, W_{\text{fuel-cap}}) + \sum \text{Nauxtank}*W_{\text{aux-cap}}$

auxiliary fuel tanks: SET_auxtank used for fallout fuel weight (SET_UL='pay')
adjust Nauxtank for first fuel tank system with SET_auxtank > 0
otherwise number of auxiliary fuel tanks fixed at input value

payload: only Wpay used if SET_Wpayload = no details
crew: only dWcrew used if SET_Wcrew = no details
equipment: dNcrew_seat and dNpass_seat require non-zero weight per seat

		+	Parameter sweep	
SET_sweep	int	+	sweep (0 for none, 1 from list, 2 from range)	0
KIND_sweep	int	+	kind (1 single sweep sequence, 2 nested sweeps)	1
INIT_sweep	int	+	initialize trim (0 for not)	0
nquant_sweep	int	+	number of swept quantities (1 to qsweepmax)	1
quant_sweep(qsweepmax)	c*12	+	quantity (parameter name)	
		+	range	
sweep_first(qsweepmax)	real	+	first parameter value	
sweep_last(qsweepmax)	real	+	last parameter value	
sweep_inc(qsweepmax)	real	+	parameter increment	
		+	list	
nsweep(qsweepmax)	int	+	number of values (maximum nsweepmax)	
sweep(nsweepmax,qsweepmax)	real	+	parameter values	

Parameter sweep: only for performance flight conditions, not sizing flight conditions
maximum total number of values for all conditions is nsweepmax
KIND_sweep: single sweep, simultaneously varying nquant_sweep quantities; or nquant_sweep nested sweeps
Sweeps executed from sweep_last to sweep_first
sweep analyzed using single data structure, only solution for sweep_first saved (last value executed)
sweep_last (first value executed) should be condition that will converge
sign of parameter step determined by sign of (sweep_last-sweep_first); sign of sweep_inc ignored

Single sweep sequence: only use nsweep(1)
sweep_inc of first quantity determines number of values, sweep_inc of other quantities not used
INIT_sweep: control/pitch/roll values of trim iteration initialized from previous condition of sweep
Available parameters: quant_sweep = parameter name
GW, dGW, fGW, dPavn, fPavn, dTavn, fTavn, Wpay, dFueln, fFueln, dWcrew, dWequip
Vkts, Mach, ROC, climb, side, pitch, roll, rate_turn, nz_turn, bank_turn, rate_pullup, nz_pullup
ax_linear, ay_linear, az_linear, nx_linear, ny_linear, nz_linear
altitude, dtemp, temp, density, csound, viscosity, HAGL
controln, coll, latcyc, lngcyc, pedal, tilt, Vtipn, Npecn, fPower, fThrust, fCharge, fTorque
DoQ_pay, fDoQ_pay, DoQV_pay, dSLcg, dBLcg, dWLcg, trim_targetn
n = propulsion group (Vtip, Nspec, dPav, fPav), jet group (dTav, fTav), fuel tank system, control number, or trim quantity
n = 1 if absent from quant_sweep
for fPower, value is factor on input fPower for all engine groups, all propulsion groups
for fThrust, value is factor on input fThrust for all jet groups
for fCharge, value is factor on input fCharge for all charge groups
for fTorque, value is factor on input fTorque for for all propulsion groups

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parent	int	parent (1 Size, 2 Performance)
kFltCond	int	FltCond number
kcol_out	int	performance output column (first for sweep)
		Specification
iSET_GW	int	gross weight (SET_GW_xxx)
iSET_maxGW	int	max gross weight (0 no iteration; SET_GW_maxP, maxQ, maxPQ, maxJ, maxPJ, maxQJ, maxPQJ)
iSET_Wlimit	int	max gross weight limit (0 none, SET_GW_xxx)
iSET_UL	int	useful load (SET_UL_pay, fuel, payfuel)
iSETPmargin(npropmax)	int	power margin as quantity (3 max GW, 2 max effort, 1 trim); not used to size engine or rotor
iSETQmargin(npropmax)	int	torque margin as quantity (3 max GW, 2 max effort, 1 trim); not used to size transmission
iSETEmargin(nengmax)	int	power margin as quantity (3 max GW, 2 max effort, 1 trim); not used to size engine group
iSETJmargin(njetmax)	int	jet thrust margin as quantity (3 max GW, 2 max effort, 1 trim); not used to size jet group
iSETCmargin(nchrgmax)	int	charger power margin as quantity (1 trim); not used to size charge group
iSETBmargin(ntankmax)	int	battery power margin as quantity (2 max effort, 1 trim); not used to size fuel tank

isFIX_GW	int	fixed gross weight; DESIGN_GW=0, DESIGN_sdgw=0, DESIGN_wmto=0
		Parameter sweep
kquant_sweep(qsweepmax)	int	quantity number
label_sweep	c*8	quantity column label (first parameter)
msweep(qsweepmax)	int	number of values
vsweep(nsweepmax,qsweepmax)		
	real	parameter values
fPower_original(nengmax)	real	fraction of rated engine power available
fThrust_original(njetmax)	real	fraction of rated jet thrust available
fCharge_original(nchrgmax)	real	fraction of rated charger power available
fTorque_original(npropmax)	real	fraction of rated drive system torque limit

Chapter 16

Structure: Mission

Variable	Type	Description	Default
		Mission Profile	
MissParam	MissParam	Parameters	
		Mission Segments	
MissSeg(nsegmax)	MissSeg	mission segments	
FltState(nsegmax)	FltState	flight conditions	

Structure: MissParam

Variable	Type		Description	Default
		+	Mission Profile	
title	c*100	+	title	
label	c*8	+	label	
		+	Specification	
SET_GW	c*16	+	mission takeoff gross weight W_G	'pay+miss'
GW	real	+	input gross weight	0.
dGW	real	+	gross weight increment	0.
fGW	real	+	gross weight factor	1.
SET_Wlimit	c*16	+	gross weight limit	'none'
Wlimit	real	+	input gross weight limit	0.
SET_UL	c*16	+	useful load	'pay+miss'
Wpay	real	+	input takeoff payload weight W_{pay} (Units_pay)	0.
Npass	int	+	number of passengers N_{pass}	0
Wpay_cargo	real	+	cargo W_{cargo} (Units_pay)	0.
Wpay_extload	real	+	external load $W_{\text{ext-load}}$ (Units_pay)	0.
Wpay_ammo	real	+	ammunition W_{ammo} (Units_pay)	0.
Wpay_weapons	real	+	weapons W_{weapons} (Units_pay)	0.
SET_pay	c*16	+	payload changes	'delta'
		+	fuel tank systems	
FIX_missfuel(ntankmax)	int	+	mission fuel weight (0 calculated, 1 fixed)	0
dFuel(ntankmax)	real	+	fuel weight or energy increment	0.
fFuel(ntankmax)	real	+	fuel capacity factor	1.
SET_auxtank(ntankmax)	int	+	auxiliary fuel tanks (1 adjust Nauxtank, 2 only increase, 3 increase at start and drop, 0 no change)	1
mauxtank(ntankmax)	int	+	tank size changed (–1 first, –2 first size already used, m for m-th size)	-1
dNauxtank(ntankmax)	int	+	number tanks added or dropped	1
Nauxtank(nauxtankmax,ntankmax)	int	+	number of auxiliary fuel tanks N_{auxtank} (each aux tank size)	

		+	fixed useful load	
SET_foldkit	int	+	folding kit on aircraft (0 none, 1 present)	1
SET_reserve	int	+	fuel reserve (1 fraction mission fuel, 2 fraction fuel capacity, 3 only mission segments)	1
fReserve	real	+	fuel reserve fraction $f_{\rm res}$	0.
		+	split segments	
dist_inc	real	+	distance increment (Units_dist)	100.
time_inc	real	+	time increment (Units_time)	30.
alt_inc	real	+	altitude increment (Units_alt)	2000.
VTO_inc	real	+	takeoff velocity increment	10.
hTO_inc	real	+	takeoff height increment	10.
DESIGN_engine	int	+	design mission for power (1 to use for engine sizing)	1
DESIGN_jet	int	+	design mission for jet thrust (1 to use for jet group sizing)	1
DESIGN_charge	int	+	design mission for charge power (1 to use for charge group sizing)	1
DESIGN_GW	int	+	design mission for DGW (1 to use for DGW calculation)	1
DESIGN_xmsn	int	+	design mission for transmission (1 to use for transmission sizing)	1
DESIGN_tank	int	+	design mission for fuel tank (1 to use for fuel tank capacity)	1
DESIGN_thrust	int	+	design mission for antitorque or aux thrust (1 to use for rotor sizing)	1

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label is short description for output
sizing mission: use all parameters
fixed gross weight missions not used to determine DGW (set DESIGN_GW=0)
mission segment not used to size engine or rotor if power margin fixed (max GW, max effort, or trim)
mission segment not used to size transmission if zero torque margin (max GW, max effort, or trim)
mission segment not used for sizing if set MissSeg%SizeZZZ=0
off design mission: not use DESIGN_xx
SET_GW, SET_UL values determine which input parameters used

SET_GW, set mission takeoff gross weight W_G:
'DGW' = design gross weight W_D; input (FIX_DGW) or calculated
'SDGW' = structural design gross weight W_{SD} (may depend on DGW)
'WMTO' = maximum takeoff gross weight W_{MTO} (may depend on DGW)
'f(DGW)' = function DGW: fGW*W_D+dGW
'f(SDGW)' = function SDGW: fGW*W_{SD}+dGW
'f(WMTO)' = function WMTO: fGW*W_{MTO}+dGW

'input' = input (use GW)
'maxP', 'max' = maximum GW for power required equal specified power: $P_{req} =$ fPav$P_{av} +$ dPav
at mission segment MaxGW, minimum gross weight of designated segments
$\min((fP_{avPG} + d) - P_{reqPG}) = 0$, over all propulsion groups
'maxQ' = maximum GW for transmission torque equal limit: zero torque margin
at mission segment MaxGW, minimum gross weight of designated segments
$\min(P_{\text{limit}} - P_{req}) = 0$, over all propulsion groups, engine groups, and rotors
'maxPQ', 'maxQP' = maximum GW for power required equal specified power and transmission torque equal limit
at mission segment MaxGW, minimum gross weight of designated segments
most restrictive of power and torque margins
'maxJ' = maximum GW for jet thrust required equal specified thrust: $T_{req} =$ fTav$T_{av} +$ dTav
at mission segment MaxGW, minimum gross weight of designated segments
$\min((fT_{avJG} + d) - T_{reqJG}) = 0$, over all jet groups
'maxPJ', 'maxQJ', 'maxPQJ' = maximum GW for most restrictive of power, torque, and thrust margins
'pay+fuel' = input payload and fuel weights; gross weight fallout
'pay+miss' = input payload, fuel weight from mission; gross weight fallout

SET_Wlimit: weight limit for SET_GW='max'
'none' = no limit
'f(DGW)' = function DGW: fGW*W_D+dGW
'f(SDGW)' = function SDGW: fGW*W_{SD}+dGW
'f(WMTO)' = function WMTO: fGW*W_{MTO}+dGW
'input' = input (use Wlimit)

SET_UL, set useful load:
'pay' = input payload weight (Wpay); fuel weight fallout
'fuel' = input fuel weight (dFuel, fFuel, Nauxtank); initial payload weight fallout
'miss' = fuel weight from mission; initial payload weight fallout
'pay+fuel' = input payload and fuel weights; gross weight fallout
'pay+miss' = input payload, fuel weight from mission; gross weight fallout

if SET_GW='pay+fuel' or 'pay+miss', assume SET_UL same (actual SET_UL ignored)
FIX_missfuel only used for SET_UL='miss' or 'pay+miss', with more than one fuel tank system

SET_pay, set payload changes: mission segment payload (use of MissSeg%xWpay)
'none' = no changes
'input' = value; payload = xWpay (not use Wpay)
'delta' = increment; payload = (initial payload weight)+(xWPay–xWpay(seg1))
'scale' = factor; payload = (initial payload weight)*(xWPay/xWpay(seg1))
when SET_GW='max' and SET_UL='fuel' or 'miss' (so payload is fallout), payload (from SET_pay and xWpay) must not be zero at the maximum GW segments

payload: only Wpay and xWpay used if SET_Wpayload = no details

input fuel weight: $W_{\text{fuel}} = \min(\text{dFuel}+\text{fFuel}*W_{\text{fuel-cap}}, W_{\text{fuel-cap}}) + \sum \text{Nauxtank}*W_{\text{aux-cap}}$
for fallout fuel weight, this is the initial value for the mission iteration

auxiliary fuel tanks:
SET_auxtank options: fixed; or adjust Nauxtank for each segment; or
increase at mission start, then constant; or increase at start, then drop
for input fuel (SET_UL = 'fuel' or 'pay+fuel'), start with input Nauxtank, then drop
for mission fuel (SET_UL = 'miss' or 'pay+miss'), fixed W_{fuel} or E_{fuel} at start
for fallout (SET_UL = 'pay'), adjust W_{fuel} with change in Nauxtank (fixed $W_G - W_{\text{pay}} = W_O + W_{\text{fuel}}$)
for all SET_UL, adjust W_O with change in Nauxtank
fuel tank design mission: Nauxtank=0, allow W_{fuel} or E_{fuel} to exceed tank capacity

SET_reserve: maximum of fuel for designated reserve mission segments
and fraction of fuel ($f_{\text{res}}W_{\text{burn}}$ or $f_{\text{res}}E_{\text{burn}}$) or fraction of fuel capacity ($f_{\text{res}}W_{\text{fuel-cap}}$ or $f_{\text{res}}E_{\text{fuel-cap}}$)

		+	Segment integration	
KIND_SegInt	int	+	method (0 segment start, 1 segment midpoint, 2 trapezoidal)	1
		+	Mission iteration (supersede Solution input if nonzero)	
relax_miss	real	+	relaxation factor (mission fuel)	0.
relax_range	real	+	relaxation factor (range credit)	0.
relax_gw	real	+	relaxation factor (max takeoff GW)	0.
toler_miss	real	+	tolerance (fraction reference)	0.
trace_miss	int	+	trace iteration (0 for none)	0

		+	Mission Segments	
nSeg	int	+	number of mission segments (maximum nsegmax)	1

input all mission segments as arrays in single mission namelist

parent	int	parent (1 Size, 2 OffDesign)
kMission	int	Mission number
kcol_out	int	performance output column
		Specification
iSET_GW	int	gross weight (SET_GW_xxx)
iSET_maxGW	int	max gross weight (SET_GW_maxP, maxQ, maxPQ, maxJ, maxPJ, maxQJ, maxPQJ)
nSET_maxGW	int	number max gross weight segments
iSET_Wlimit	int	max gross weight limit (0 none, SET_GW_xxx)
iSET_UL	int	useful load (SET_UL_pay, fuel, payfuel, miss, paymiss)
iSET_pay	int	payload changes (SET_pay_none, input, delta, scale)
iSETPmargin(npropmax)	int	power margin as quantity (all mission segments); not used to size engine or rotor
iSETQmargin(npropmax)	int	torque margin as quantity (all mission segments); not used to size transmission
iSETEmargin(nengmax)	int	power margin as quantity (all mission segments); not used to size engine group
iSETJmargin(njetmax)	int	jet thrust margin as quantity (all mission segments); not used to size jet group
iSETCmargin(nchrgmax)	int	charger power margin as quantity (all mission segments); not used to size charge group
iSETBmargin(ntankmax)	int	battery power margin as quantity (all mission segments); not used to size fuel tank
isFIX_GW	int	fixed gross weight; DESIGN_GW=0
		Segments
nreserve	int	number reserve segments
nadjust	int	number adjustable segments
kind_adjust	int	kind adjustable (0 none, 1 distance, 2 time)
kind_range	int	kind range credit (0 none, 1 all forward, 2 all backward, 3 both)
ntakeoff	int	number takeoff segments
		Iteration
kind_iter	int	kind iteration (0 none, 1 calculate mission fuel, 2 adjust mission, 3 only range credit or integration)

ismissconv	int	converged (0 not)
count_miss	int	number of iterations
error_miss(3)	real	error ratio (Wfuel, range credit, takeoff GW)
		residuals (difference after one mission iteration)
resid_fuel(ntankmax)	real	fuel Wfuel or Efuel
resid_rangecredit	real	range credit
resid_TOGW	real	takeoff gross weight
		Mission quantities
isFirstSol	int	first solution (initialize GW_to and Wfuel_to)
GW_to	real	takeoff gross weight (start of mission)
GW_endmiss	real	gross weight (end of mission, excluding reserve segments; last non-reserve segment)
GW_end	real	gross weight (end of mission; last segment)
Wfuel_to(ntankmax)	real	takeoff fuel weight (start of mission)
Wfuel_add(ntankmax)	real	added fuel weight (fill/add/drop during mission)
Wfuel_endmiss(ntankmax)	real	fuel weight (end of mission, excluding reserve segments; last non-reserve segment)
Wfuel_end(ntankmax)	real	fuel weight (end of mission; last segment)
Wfuel_max(ntankmax)	real	maximum fuel weight in tank (all segments)
Wfuel_net(ntankmax)	real	maximum net (burn-add) fuel used (all segments)
Wburn(ntankmax)	real	weight fuel burned $W_{\rm burn}$
Wres(ntankmax)	real	weight reserve fuel $W_{\rm res}$ (maximum of fraction or reserve segments)
Wfuel_miss(ntankmax)	real	calculated mission fuel weight ($W_{\rm burn} + W_{\rm res}$)
Efuel_to(ntankmax)	real	takeoff fuel energy (start of mission)
Efuel_add(ntankmax)	real	added fuel energy (fill/add/drop during mission)
Efuel_endmiss(ntankmax)	real	fuel energy (end of mission, excluding reserve segments; last non-reserve segment)
Efuel_end(ntankmax)	real	fuel energy (end of mission; last segment)
Efuel_max(ntankmax)	real	maximum fuel energy in tank (all segments)
Efuel_net(ntankmax)	real	maximum net (burn-add) fuel energy used (all segments)
Eburn(ntankmax)	real	energy fuel burned $E_{\rm burn}$
Eres(ntankmax)	real	energy reserve fuel $E_{\rm res}$ (maximum of fraction or reserve segments)
Efuel_miss(ntankmax)	real	calculated mission fuel energy ($E_{\rm burn} + E_{\rm res}$)
exceedP	int	exceed power available: any mission segment $P_{reqPG} > (1+\epsilon)P_{avPG}$
exceedQ	int	exceed torque available: any mission segment $P_{reqPG} > (1+\epsilon)P_{DS{\rm limit}}$
exceedJ	int	exceed jet thrust available: any mission segment $T_{reqJG} > (1+\epsilon)T_{avJG}$
exceedC	int	exceed charger power available: any mission segment $P_{reqCG} > (1+\epsilon)P_{avCG}$

exceedWf	int	exceed fuel capacity: any mission segment $W_{\rm fuel} > (1+\epsilon)W_{\rm fuel-cap}$ or $E_{\rm fuel} > (1+\epsilon)E_{\rm fuel-cap}$
exceedB	int	exceed battery power: any mission segment $\lvert\dot{E}_{\rm batt}\rvert > (1+\epsilon)P_{\max}$
		Total mission, excluding reserve segments
endurance	real	endurance E, block time (min)
range	real	range R (nm)
airdist	real	air distance (nm)
blockspeed	real	block speed (kts; range/endurance)
range_factor	real	range factor $RF = R/\ln(W_{to}/(W_{to} - W_{\rm burn}))$ (nm)
range_factorE	real	range factor $RF = R/E_{\rm burn}$ (nm/MJ)
fuel_eff	real	fuel efficiency $e = W_{\rm pay}R/W_{\rm burn}$ (ton-nm/lb or ton-nm/kg)
fuel_effE	real	fuel efficiency $e = W_{\rm pay}R/E_{\rm burn}$ (ton-nm/MJ)
productivity_o	real	productivity $p = W_{\rm pay}V/W_O$ (ton-kt/lb or ton-kt/kg)
productivity_f	real	productivity $p = W_{\rm pay}V/W_{\rm burn}$ (ton-kt/lb or ton-kt/kg)
productivity_fE	real	productivity $p = W_{\rm pay}V/E_{\rm burn}$ (ton-kt/MJ)
fuelflow	real	average fuel flow $W_{\rm burn}/E$ (lb/hr or kg/hr)
energyflow	real	average energy flow $E_{\rm burn}/E$ (MJ/hr)
spec_range	real	average specific range $R/W_{\rm burn}$ (nm/lb or nm/kg)
spec_rangeE	real	average specific range $R/E_{\rm burn}$ (nm/MJ)
		Cost
Ndep	real	number of depatures per year $B/T_{\rm miss}$
ASM	real	available seat miles
COP	real	yearly operating cost C_{OP} (maintenance + fuel + crew + depreciation + insurance + finance + ETS)
Ctrip	real	trip operating cost $C_{OP}/N_{\rm dep}$
Cpass	real	passenger operating cost $C_{\rm trip}/(N_{\rm pass}\,{\rm LoadFactor}/100)$
xmaint	real	operating cost fraction, maintenance
xfuel	real	operating cost fraction, fuel
xcrew	real	operating cost fraction, crew
xdep	real	operating cost fraction, depreciation
xins	real	operating cost fraction, insurance
xfin	real	operating cost fraction, finance
xETS	real	operating cost fraction, ETS
DOC	real	direct operating cost $100C_{OP}/{\rm ASM}$

		Emissions Trading Scheme (kg CO2, per mission)
ETS	real	total
ETS_fuel	real	fuel burned
ETS_energy	real	energy used
		Weight of emissions (kg, per mission)
W_CO2	real	carbon dioxide
W_NOx	real	NO_x
W_H2O	real	water vapor
W_soot	real	soot
W_SO4	real	sulphates
		Average Temperature Response (deg C)
ATR	real	total
ATR_noAIC	real	total without AIC
ATR_CO2	real	carbon dioxide
ATR_CH4	real	NO_x - methane
ATR_O3L	real	NO_x - ozone (long life)
ATR_O3S	real	NO_x - ozone (short life)
ATR_H2O	real	water vapor
ATR_soot	real	soot
ATR_SO4	real	sulphates
ATR_AIC	real	aviation induced cloudiness

Chapter 18

Structure: MissSeg

Variable	Type		Description	Default
		+	Segment definition	
label_seg	c*8	+	label	' '
kind	c*12	+	kind	'dist'
dist	real	+	distance D (Units_dist)	0.
time	real	+	time T (Units_time)	0.
		+	segment	
reserve	int	+	reserve (0 for not)	0
adjust	int	+	adjustable for flexible mission (0 for not)	0
range_credit	int	+	segment number for range credit (0 for no reassignment)	0
ignore	int	+	ignore segment (0 for not)	0
copy	int	+	copy segment (source segment number)	0
split	int	+	split segment (number segments; –1 calculated; 0 for not split)	0
SET_tank(ntankmax)	int	+	segment fuel use or replace	0
dTank(ntankmax)	real	+	fuel increment	0.
fTank(ntankmax)	real	+	fuel factor	1.
SET_refuel(ntankmax)	int	+	refuel (0 not, 1 fill all tanks, 2/8 add fuel, 3/9 drop fuel, 4-5 fill/add below rWfuel, 6-7 fill/add below mWfuel)	0
xWfuel(ntankmax)	real	+	fuel weight or energy change	0.
rWfuel(ntankmax)	real	+	threshold fraction	0.
mWfuel(ntankmax)	real	+	threshold weight or energy	0.
		+	gross weight	
MaxGW	int	+	maximize gross weight (0 not)	0
dPav(npropmax)	real	+	power increment, each propulsion group	0.
fPav(npropmax)	real	+	power factor, each propulsion group	1.
dTav(njetmax)	real	+	thrust increment, each jet group	0.
fTav(njetmax)	real	+	thrust factor, each jet group	1.
		+	useful load	
xWpay	real	+	payload weight change (Units_pay)	0.
xNpass	int	+	number of passengers increment $\delta N_{\rm pass}$	0

		+	fixed useful load	
dWcrew	real	+	crew weight increment	0.
dNcrew	int	+	number of crew increment $\delta N_{\rm crew}$	0
dWoful(10)	real	+	other fixed useful load increment (nWoful categories)	0.
dWequip	real	+	equipment weight increment	0.
dNcrew_seat	int	+	crew seat increment $\delta N_{\rm crew-seat}$	0
dNpass_seat	int	+	passenger seat increment $\delta N_{\rm pass-seat}$	0
		+	kits on aircraft (0 none, 1 present)	
SET_extkit(nwingmax)	int	+	wing extension kit	1
SET_wingkit(nwingmax)	int	+	wing kit	1
SET_otherkit	int	+	other kit	0
SET_alt	int	+	altitude at start of segment (0 input, 1 from previous segment, 2 from kSeg_alt)	0
kSeg_alt	int	+	source of altitude	0
		+	design mission (0 to not use segment for sizing)	
SizeEngine	int	+	power	1
SizeJet	int	+	jet thrust	1
SizeCharge	int	+	charger power	1
SizeGW	int	+	DGW	1
SizeXmsn	int	+	transmission	1
SizeThrust	int	+	antitorque or aux thrust	1

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segment kind
- kind='taxi', 'idle': taxi/warm-up mission segment (use time)
- kind='dist': fly segment for specified distance (use dist)
- kind='time': fly segment for specified time (use time)
- kind='hold', 'loiter': fly segment for specified time (use time), fuel burned but no distance added to range
- kind='climb': climb/descend from present altitude to next segment altitude
- kind='spiral': climb/descend from present altitude to next segment altitude, fuel burned but no dist added to range
- kind='fuel': use or replace specified fuel amount, calculate time and distance
- kind='burn', 'charge': use or replace specified fuel amount, calculate time but no distance added to range
- kind='takeoff', 'TO': takeoff distance calculation

only one of reserve, adjust, range_credit designations for each segment
reserve: time and distance not included in block time and range

range credit: to facilitate specification of range
range calculated for this segment credited to segment = range_credit
range_credit segment must be kind='dist', specified distance is for group of segments
actual distance flown in range_credit segment is specified dist less distances from other segments
if credit to earlier segment, iteration required
adjustable: for SET_UL not 'miss', can adjust one or more segments
if more than one segment adjusted, must be all kind='dist' or all kind='time'/'hold'
adjust time or distance based on fuel burn (proportional to initial values)

split segment: number specified, or calculated from MissParam%dest_inc, time_inc, alt_inc

ignore segment: removed from input; segments using MaxGW, range_credit, FltCond%KIND_source can not be ignored

SET_tank: segment fuel use or replace for kind='fuel' or 'burn'; distance and time calculated
SET_tank = 0: no requirement
SET_tank = 1: target dTank+fTank*$W_{\text{fuel}-\text{cap}}$ or dTank+fTank*$E_{\text{fuel}-\text{cap}}$
SET_tank = 2: target dTank+fTank*W_{fuel} or dTank+fTank*E_{fuel}
SET_tank = 3: increment dTank+fTank*$W_{\text{fuel}-\text{cap}}$ or dTank+fTank*$E_{\text{fuel}-\text{cap}}$
SET_tank = 4: increment dTank+fTank*W_{fuel} or dTank+fTank*E_{fuel}
charge if $\dot{E} < 0$ (not based on keyword, increment always positive)
target limited by capacity, if target already achieved then no requirement
increment limited by current fuel (use) or capacity minus current fuel (replace)

SET_refuel, refuel: change at start of segment; weight or energy; no contribution to distance or time
SET_refuel = 1: fill all tanks (including any auxiliary tanks installed)
SET_refuel = 2: add fuel xWfuel
SET_refuel = 3: drop fuel xWfuel
SET_refuel = 4: if below fraction rWfuel of fuel capacity (including auxiliary tanks), fill all tanks
SET_refuel = 5: if below fraction rWfuel of fuel capacity (including auxiliary tanks), add xWfuel
SET_refuel = 6: if below mWfuel, fill all tanks
SET_refuel = 7: if below mWfuel, add xWfuel
SET_refuel = 8: add fraction rWfuel of fuel capacity (including auxiliary tanks)
SET_refuel = 9: drop fraction rWfuel of fuel capacity (including auxiliary tanks)
added fuel limited by capacity (unless sizing fuel tank); not used for first segment
xWfuel positive (add or drop determined by SET_refuel)

maximize gross weight: MaxGW designate segments if SET_GW='maxP' or 'maxQ' or 'maxPQ'

climb/descend or spiral segment: end altitude is that of next segment; last segment kind can not be climb or spiral
begin altitude is that input for this segment (SET_alt=0), or altitude of previous segment (SET_alt=1),

payload: only Wpay and xWpay used if SET_Wpayload = no details
xNpass is change from MissParam%Npass
crew: only dWcrew used if SET_Wcrew = no details
equipment: dNcrew_seat and dNpass_seat require non-zero weight per seat

		+	Takeoff distance calculation	
SET_takeoff	c*12	+	takeoff segment kind	'none'
Vkts_takeoff	real	+	ground speed or climb speed (knots, CAS)	0.
climb_takeoff	real	+	climb angle relative ground γ (deg)	0.
height_takeoff	real	+	height during climb h (ft or m)	0.
slope_ground	real	+	slope of ground γ_G (+ for uphill; deg)	0.
friction	real	+	friction coefficient μ	0.04
t_decision	real	+	decision delay after engine failure t_1 (sec)	1.5
t_rotation	real	+	rotation time t_R (sec)	2.0
nz_transition	real	+	transition load factor n_{TR}	1.2

takeoff distance calculation: set of consecutive kind='takeoff' segments
first segment identified by SET_takeoff='start' ($V = 0$)
last segment if next segment is not kind='takeoff', or is SET_takeoff='start'
takeoff segment kind
SET_takeoff='start', 'ground run' (keyword = ground or run), 'engine fail' (keyword = eng or fail)
SET_takeoff='liftoff', 'rotation', 'transition', 'climb', 'brake'
each segment requires appropriate configuration, trim option, max effort specification
not use dist, time, reserve, adjust, range_credit, SET_refuel, MaxGW, SET_alt
max_var='alt' not allowed in maximum effort
velocity specification (SET_vel) and HAGL superseded; SET_turn=SET_pullup=0
can split segment (except start, rotation, transition): split height for climb, velocity for others
splitting liftoff or engine failure segment produces additional ground run segments

separate definition of multiple ground run, climb, brake segments allows configuration variations
define takeoff profile in terms of velocities
- integrate acceleration vs velocity to obtain time and distance
- segments correspond to ends of integration intervals
- analysis checks for consistency of input velocity and calculated acceleration
- analysis checks for consistency of input height and input/calculated climb angle

takeoff distance definition: includes SET_takeoff='liftoff' segment
- order: start, ground run, engine failure, ground run, liftoff, rotation, transition, climb
- only one liftoff; only one engine failure, rotation, transition (or none)
- engine failure before liftoff; all ground run before liftoff, all climb after liftoff

accelerate-stop distance definition: does not have SET_takeoff='liftoff' segment
- order: start, ground run, engine failure, brake
- only one engine failure (or none)

engine failure segment (if present) identifies point for decision delay
- until t_decision after engine failure segment, use engine rating, fPower, fraction of engine failure segment
- so engine failure segment corresponds to conditions before failure

number of inoperative engines specified by nEngInop for each segment
- if engine failure segment present, nEngInop specification must be consistent

---

parent	int	parent (1 Size, 2 OffDesign)
kMission	int	Mission number
kMissSeg	int	MissSeg number
kcol_out	int	performance output column
		Specification
ikind	int	kind (MissSeg_kind_taxi, dist, time, hold, climb, spiral, fuel, burn)
SET_foldkit	int	folding kit on aircraft (0 none, 1 present)

		Segments
kind_range	int	this segment receives range credit (0 not, 1 source forward, 2 source backward, 3 both)
fadjust	real	adjustment ratio (initial time or dist ratio)
wassplit	int	split segment (number segments; 0 for not split)
ksplit_first	int	first segment after split
ksplit_last	int	last segment after split
dWpay	real	payload increment (xWpay–xWpay(seg1)) or factor (xWpay/xWpay(seg1))
iSET_maxGW	int	max gross weight (0 no iteration; SET_GW_maxP, maxQ, maxPQ, maxJ, maxPJ, maxQJ, maxPQJ + maxGW)
iSETPmargin(npropmax)	int	power margin as quantity (3 max GW, 2 max effort, 1 trim)
iSETQmargin(npropmax)	int	torque margin as quantity (3 max GW, 2 max effort, 1 trim)
iSETEmargin(nengmax)	int	power margin as quantity (3 max GW, 2 max effort, 1 trim)
iSETJmargin(njetmax)	int	jet thrust margin as quantity (3 max GW, 2 max effort, 1 trim)
iSETCmargin(nchrgmax)	int	charger power margin as quantity (1 trim)
iSETBmargin(ntankmax)	int	battery power margin as quantity (2 max effort, 1 trim)
		Maximum gross weight
ismaxgwconv	int	converged (0 not)
count_maxgw	int	number of iterations
error_maxgw	real	error ratio
GW_inc	real	gross weight increment
		Takeoff distance calculation
iSET_takeoff	int	takeoff segment kind (SET_takeoff_xxx)
VCAS_TO	real	ground speed or climb speed (CAS)
V_TO	real	ground speed (ft/sec or m/sec)
climb_TO	real	angle relative ground (deg)
isConsistent_TO	int	consistent acc and V change, climb and h change
FxG_TO	real	net force $T - D$ (ground axes)
FzG_TO	real	net force $W - L$ (ground axes)
FzGmu_TO	real	friction drag μF_{zG}
acc_TO	real	acceration (ground axes)
h_TO	real	height (ft or m)
t_TO	real	time (sec)
s_TO	real	distance (ft or m)
time_TO	real	cumulative time (sec)
dist_TO	real	cumulative distance (ft or m)

		original value for engine failure decision (from FltAircraft)
rating_original(nengmax)	c*12	engine rating
krate_original(nengmax)	int	engine rating
fPower_original(nengmax)	real	fraction of rated engine power available
rating_jet_original(njetmax)	c*12	jet rating
krate_jet_original(njetmax)	int	jet rating
fThrust_original(njetmax)	real	fraction of rated jet thrust available
rating_charge_original(nchrgmax)	c*12	charger rating
krate_charge_original(nchrgmax)	int	charger rating
fCharge_original(nchrgmax)	real	fraction of rated charger power available
friction_original	real	friction coefficient
kSegEF_TO	int	engine failure segment (0 for none)
		Performance (from FltState; at start or midpoint)
speed	real	horizontal speed V_h (knots)
Vclimb	real	climb velocity V_c (ft/sec or m/sec)
fuelflow(ntankmax)	real	fuel flow $\dot{w}$ (lb/hr or kg/hr)
energyflow(ntankmax)	real	energy flow $\dot{E}$ (MJ/hr)
		trapezoidal integration
speed_start	real	horizontal speed V_h
Vclimb_start	real	climb velocity V_c
fuelflow_start(ntankmax)	real	fuel flow $\dot{w}$
energyflow_start(ntankmax)	real	energy flow $\dot{E}$
speed_end	real	horizontal speed V_h
Vclimb_end	real	climb velocity V_c
fuelflow_end(ntankmax)	real	fuel flow $\dot{w}$
energyflow_end(ntankmax)	real	energy flow $\dot{E}$
alt_start	real	altitude h at start of segment (ft or m)
alt_end	real	altitude h at end of segment (from start of next segment, only used for kind='climb' or 'spiral')
Wind	real	Headwind V_w (knots)
groundspeed	real	Ground speed $V_g = V_h - V_w$ (knots)

		Mission segment quantities
T	real	time T (minutes)
D	real	ground distance D (nm)
otherDpast	real	distance from past range credit (nm)
otherDfuture	real	distance from future range credit (nm)
dR	real	range contribution dR (nm)
airdist	real	air distance (nm)
Wburn(ntankmax)	real	fuel burned $W_{\rm burn}$ (lb or kg)
Wfuel_add(ntankmax)	real	fuel added or dropped at start of segment
Wfuel_start(ntankmax)	real	fuel weight $W_{\rm fuel}$ (segment start)
Eburn(ntankmax)	real	fuel burned $E_{\rm burn}$ (MJ)
Efuel_add(ntankmax)	real	fuel added or dropped at start of segment
Efuel_start(ntankmax)	real	fuel energy $E_{\rm fuel}$ (segment start)
GW_start	real	gross weight W_G (segment start)
		Emissions Trading Scheme (kg CO2, per mission)
ETS	real	total
ETS_fuel	real	fuel burned
ETS_energy	real	energy used
		Weight of emissions (kg, per mission)
W_CO2	real	carbon dioxide
W_NOx	real	NO_x
W_H2O	real	water vapor
W_soot	real	soot
W_SO4	real	sulphates
		Average Temperature Response (deg C)
ATR	real	total
ATR_noAIC	real	total without AIC
ATR_CO2	real	carbon dioxide
ATR_CH4	real	NO_x - methane
ATR_O3L	real	NO_x - ozone (long life)
ATR_O3S	real	NO_x - ozone (short life)
ATR_H2O	real	water vapor
ATR_soot	real	soot
ATR_SO4	real	sulphates

ATR_AIC	real	aviation induced cloudiness
EI_NOx(ntankmax)	real	$EI_{\mathrm{NO}_x} = \sum EI\dot{w} / \sum \dot{w}$, input or turboshaft calculated, weighted for engine group
fPto(nengmax)	real	$f_P = P_q/P_{to}$ for $\dot{w}$

Chapter 19

Structure: FltState

Variable	Type	Description	Default
		Flight State	
FltAircraft	FltAircraft	Aircraft	
		Components	
FltFuse	FltFuse	fuselage	
FltGear	FltGear	landing gear	
FltRotor(nrotormax)	FltRotor	rotors	
FltWing(nwingmax)	FltWing	wings	
FltTail(ntailmax)	FltTail	tails	
FltTank(ntankmax)	FltTank	fuel tank systems	
FltProp(npropmax)	FltProp	propulsion groups	
FltEngn(nengmax)	FltEngn	engine groups	
FltJet(njetmax)	FltJet	jet groups	
FltChrg(nchrgmax)	FltChrg	charge groups	

Chapter 20

Structure: FltAircraft

Variable	Type		Description	Default
		+	Flight State	
		+	Specification	
SET_max	int	+	maximum effort performance (maximum 2, 0 to analyze specified condition)	0
max_quant(2)	c*12	+	quantity	' '
max_var(2)	c*12	+	variable	' '
max_limit(2)	int	+	switch quantity if exceed limit (0 not, 1 power margin, 2 torque margin, 3 both)	0
max_Vlimit(2)	int	+	velocity limited by V_{NE} (0 not)	0
fVel(2)	real	+	flight speed factor	1.
SET_vel	c*12	+	flight speed	'general'
Vkts	real	+	horizontal velocity V_h (TAS or CAS or IAS, Units_vel)	0.
Mach	real	+	horizontal velocity M (Mach number)	0.
ROC	real	+	vertical rate of climb V_c (Units_ROC)	0.
climb	real	+	climb angle θ_V (deg)	0.
side	real	+	sideslip angle ψ_V (deg)	0.
		+	aircraft motion	
SET_pitch	int	+	pitch motion specification (0 Aircraft value, 1 FltState input)	1
SET_roll	int	+	roll motion specification (0 Aircraft value, 1 FltState input)	1
pitch	real	+	pitch θ_F	0.
roll	real	+	roll ϕ_F	0.
SET_turn	int	+	turn specification (0 zero, 1 turn rate, 2 load factor, 3 bank angle)	0
rate_turn	real	+	turn rate $\dot{\psi}_F$ (deg/sec)	0.
nz_turn	real	+	load factor n (g)	1.
bank_turn	real	+	bank angle ϕ_F (deg)	0.
SET_pullup	int	+	pullup specification (0 zero, 1 pitch rate, 2 load factor)	0
rate_pullup	real	+	pitch rate $\dot{\theta}_F$ (deg/sec)	0.
nz_pullup	real	+	load factor n (g)	1.
SET_acc	int	+	linear acceleration specification (0 zero, 1 acceleration, 2 load factor)	0
ax_linear	real	+	x-acceleration a_{ACx} (ft/sec^2 or m/sec^2)	0.

ay_linear	real	+	y-acceleration a_{ACy} (ft/sec^2 or m/sec^2)	0.
az_linear	real	+	z-acceleration a_{ACz} (ft/sec^2 or m/sec^2)	0.
nx_linear	real	+	x-load factor increment n_{Lx} (g)	0.
ny_linear	real	+	y-load factor increment n_{Ly} (g)	0.
nz_linear	real	+	z-load factor increment n_{Lz} (g)	0.
altitude	real	+	altitude h (Units_alt)	0.
SET_atmos	c*12	+	atmosphere specification	'std'
temp	real	+	temperature τ (Units_temp)	
dtemp	real	+	temperature increment ΔT (Units_temp)	0.
density	real	+	density ρ	
csound	real	+	speed of sound c_s	
viscosity	real	+	viscosity μ	
SET_wind	int	+	wind specification (0 none, 1 headwind, 2 tailwind)	0
dWind	real	+	wind increment, knots (dWind+fWind*altitude)	0.
fWind	real	+	wind gradient, knots (dWind+fWind*altitude)	0.
SET_GE	int	+	ground effect (0 OGE, 1 IGE)	0
HAGL	real	+	height of landing gear above ground level h_{LG}	999.
STATE_LG	c*12	+	landing gear state	'default'
STATE_control	int	+	aircraft control state	1
SET_control(ncontmax)	int	+	control specification (0 Aircraft value, 1 FltState input)	1
SET_coll	int	+	collective stick	1
SET_latcyc	int	+	lateral cyclic stick	1
SET_lngcyc	int	+	longitudinal cyclic stick	1
SET_pedal	int	+	pedal	1
SET_tilt	int	+	tilt (0 Aircraft value, 1 FltState input, 2 Aircraft conversion schedule)	1
control(ncontmax)	real	+	aircraft controls	
coll	real	+	collective stick c_{AC0}	0.
latcyc	real	+	lateral cyclic stick c_{ACc}	0.
lngcyc	real	+	longitudinal cyclic stick c_{ACs}	0.
pedal	real	+	pedal c_{ACp}	0.
tilt	real	+	tilt α_{tilt}	0.
SET_comp_control	int	+	use component control (0 for $c = Tc_{AC}$; 1 for $c = Tc_{AC} + c_0$)	1
SET_cg	int	+	center of gravity specification (0 baseline plus increment, 1 input)	0
dSLcg	real	+	stationline	0.

dBLcg	real	+	buttline	0.
dWLcg	real	+	waterline	0.
		+	Specification, each propulsion group	
SET_Vtip(npropmax)	c*12	+	rotor tip speed specification	'hover'
Vtip(npropmax)	real	+	tip speed	
Mtip(npropmax)	real	+	tip Mach number M_{tip}	
mu_Vtip(npropmax)	real	+	tip speed from μ	
Mat_Vtip(npropmax)	real	+	tip speed from M_{at}	
Nrotor(npropmax)	real	+	rotor speed (rpm)	
Nspec(npropmax)	real	+	engine speed (rpm)	
STATE_gear(npropmax)	int	+	drive system state	1
rating_ds(npropmax)	c*12	+	drive system rating	' '
fTorque(npropmax)	real	+	fraction of rated drive system torque limit f_Q (0. to 1.+)	1.
SET_Plimit(npropmax)	int	+	drive system limit (0 not applied to power available)	1
SET_Qlimit_rs(npropmax)	int	+	rotor shaft limit (0 not used for torque margin)	1
SET_Pmargin(npropmax)	int	+	power and torque margin (0 not used for maximum effort)	1
dPacc(npropmax)	real	+	accessory power increment dP_{acc}	0.
		+	Specification, each engine group	
rating(nengmax)	c*12	+	engine rating	'MCP'
fPower(nengmax)	real	+	fraction of rated engine power available f_P (0. to 1.+)	1.
nEngInop(nengmax)	int	+	number of inoperative engines N_{inop}	0
SET_Preq(nengmax)	int	+	power required (1 distributed, 2 fixed A, 3 fixed AP_{av}, 4 fixed AP_{eng})	1
STATE_IRS(nengmax)	int	+	IR suppressor system state (0 off, hot exhaust; 1 on, suppressed exhaust)	0
		+	Specification, each jet group	
rating_jet(njetmax)	c*12	+	jet rating	'MCT'
fThrust(njetmax)	real	+	fraction of rated jet thrust available f_T (0. to 1.+)	1.
nJetInop(njetmax)	int	+	number of inoperative jets N_{inop}	0
SET_Jreq(njetmax)	int	+	thrust required (1 from component, 2 fixed A, 3 fixed AT_{av}, 4 fixed AT_{jet})	2
STATE_IRS_jet(njetmax)	int	+	IR suppressor system state (0 off, hot exhaust; 1 on, suppressed exhaust)	0
		+	Specification, each charge group	
rating_charge(nchrgmax)	c*12	+	charger rating	'MCP'
fCharge(nchrgmax)	real	+	fraction of rated charger power available f_C (0. to 1.+)	1.
nChrgInop(nchrgmax)	int	+	number of inoperative chargers N_{inop}	0
SET_Creq(nchrgmax)	int	+	power required (2 fixed A, 4 fixed AP_{chrg})	2

dPeq(ntankmax)	real	+	Equipment power increment $dP_{\rm eq}$, each fuel tank	0.
		+	Specification, each fuel tank (battery)	
ffade(ntankmax)	real	+	battery capacity fade factor	1.
Tcell(ntankmax)	real	+	cell temperature (deg C)	20.
fcurrent(ntankmax)	real	+	maximum current (fraction x_{mbd} or $x_{CC\max}$)	1.
		+	Specification, each rotor	
STOP_rotor(nrotormax)	int	+	rotor stop/stow (0 not, 1 stop, 2 stop and stow, 3 stop as wing)	0
STATE_deice	int	+	Deice system state (0 off)	0
		+	Performance	
DoQ_pay	real	+	payload forward flight drag increment D/q (Units_drag)	0.
fDoQ_pay	real	+	payload drag increment scaling with weight $\Delta(D/q)/W_{\rm pay}$ (Units_drag, Units_pay)	0.
DoQV_pay	real	+	payload vertical drag increment D/q (Units_drag)	0.
		+	Rotor (nonzero to supersede rotor model)	
Ki(nrotormax)	real	+	induced power factor κ	0.
cdo(nrotormax)	real	+	profile power mean c_d	0.
MODEL_Ftpp(nrotormax)	int	+	inplane forces, tip-path plane axes (1 neglect, 2 blade-element theory)	0
MODEL_Fpro(nrotormax)	int	+	inplane forces, profile (1 simplified, 2 blade element theory, 3 neglect)	0
KIND_control(nrotormax)	int	+	control mode (1 thrust and TPP, 2 thrust and NFP, 3 pitch and TPP, 4 pitch and NFP)	0
		+	Trim solution	
STATE_trim	c*12	+	aircraft trim state (match IDENT_trim, 'none' for no trim)	'none'
trim_target(mtrimmax)	real	+	trim quantity targets	
		+	Iterations (supersede Solution input if nonzero)	
		+	relaxation factor	
relax_rotor	real	+	all rotors	0.
relax_trim	real	+	trim	0.
relax_fly(2)	real	+	maximum effort	0.
relax_maxgw	real	+	maximum gross weight	0.
		+	tolerance (fraction reference)	
toler_rotor	real	+	all rotors	0.
toler_trim	real	+	trim	0.
toler_fly(2)	real	+	maximum effort	0.
toler_maxgw	real	+	maximum gross weight	0.
		+	reinitialize aircraft controls (0 no, 1 force retrim)	
init_trim	int	+	trim	0

init_fly	int	+	maximum effort	0
		+	variable perturbation amplitude (fraction reference, 0. for no limit)	
perturb_trim	real	+	trim	0.
perturb_fly(2)	real	+	maximum effort	0.
perturb_maxgw	real	+	maximum gross weight	0.
		+	maximum derivative amplitude (0. for no limit)	
maxderiv_fly(2)	real	+	maximum effort	0.
maxderiv_maxgw	real	+	maximum gross weight	0.
		+	maximum increment fraction (0. for no limit)	
maxinc_fly(2)	real	+	maximum effort	0.
maxinc_maxgw	real	+	maximum gross weight	0.
		+	solution method	
method_flymax(2)	int	+	maximum effort	0
		+	trace iteration (0 for none)	
trace_rotor	int	+	all rotors	0
trace_trim	int	+	trim (2 for component controls)	0
trace_fly(2)	int	+	maximum effort	0
trace_maxgw	int	+	maximum gross weight	0

---

maximum effort performance: one or two quantity/variable identified; first is inner loop
- two variables must be unique
- two variables can be identified for same maximized quantity (endurance, range, climb)
- quantity identified by max_quant maximized for endurance, range, climb, or ceiling; otherwise driven to zero

- ROC or altitude can be outer loop quantity only if it is also inner loop variable
- fVel is only used for max_var='speed' or 'ROC'
- ceiling calculation should use 'Pmargin'/'alt' as inner loop, 'power'/'speed' as outer loop
- best range calculation often requires maxinc_fly=0.1 for convergence
- ROC for zero power margin initialized based on level flight power margin if input ROC=0
- max_quant='rotor(s) n' uses Rotor%CTs_steady, max_quant='rotor(t) n' uses Rotor%CTs_tran
- max_quant='rotor(e) n' uses equation for rotor thrust capability (Rotor%K0_limit and Rotor%K1_limit)
- if energy burned (not weight) or multiple fuels, use equivalent fuel flow obtained from weighted energy flow
- max_var='Vtip' or 'Nspec' requires FltAircraft%SET_Vtip='input'
- if trailing "n" is absent, use first component (n=1)

max_limit: switch quantity to power and/or torque margin if margin negative; useful for best range

description	max_quant	
endurance	'end'	maximum (1/fuelflow)
range (high side)	'range'	0.99 maximum (V/fuelflow)
range	'range(100)'	maximum (V/fuelflow)
range (low side)	'range(low)'	0.99 maximum (V/fuelflow), low side
range (high side), ground speed	'rangeVg'	0.99 maximum (V_g/fuelflow)
range, ground speed	'range(100)Vg'	maximum (V_g/fuelflow)
range (low side), ground speed	'range(low)Vg'	0.99 maximum (V_g/fuelflow), low side
climb or descent rate	'climb', 'ROC'	maximum (ROC)
climb rate (power)	'power'	maximum (1/Power)
climb or descent angle	'angle'	maximum (ROC/V)
climb angle (power)	'power/V'	maximum (V/Power)
ceiling	'alt'	maximum (altitude)
power margin	'P margin'	$\min(P_{av} - P_{req}) = 0$ (all propulsion groups)
torque margin	'Q margin',	$\min(Q_{\text{limit}} - Q_{req}) = 0$ (all limits)
jet thrust margin	'J margin',	$\min(T_{av} - T_{req}) = 0$ (all jet groups)
power and torque margin	'PQ margin',	most restrictive
power and thrust margin	'PJ margin',	most restrictive
torque and thrust margin	'QJ margin',	most restrictive
power, torque, thrust margin	'PQJ margin',	most restrictive
battery power margin	'B margin'	$\min(P_{\max} - \lvert\dot{E}_{\text{batt}}\rvert) = 0$ (all fuel tanks)
rotor thrust margin	'rotor(t) n'	$(C_T/\sigma)_{\max} - \lvert C_T/\sigma\rvert = 0$ (transient)
rotor thrust margin	'rotor(s) n'	$(C_T/\sigma)_{\max} - \lvert C_T/\sigma\rvert = 0$ (sustained)
rotor thrust margin	'rotor(e) n'	$(C_T/\sigma)_{\max} - \lvert C_T/\sigma\rvert = 0$ (equation)
wing lift margin	'stall n'	$C_{L\max} - C_L = 0$

description	max_var	
horizontal velocity	'speed'	times fVel
vertical rate of climb	'ROC'	times fVel
aircraft velocity	'side'	sideslip angle
altitude	'alt'	
aircraft angular rate	'pullup', 'turn'	Euler angle rates
aircraft acceleration	'xacc', 'yacc', 'zacc'	linear, airframe axes
aircraft acceleration	'xaccI', 'yaccI', 'zaccI'	linear, inertial axes
aircraft acceleration	'xaccG', 'yaccG', 'zaccG'	linear, ground axes
aircraft control	match IDENT_control	
aircraft orientation	'pitch', 'roll'	body axes relative inertial axes
propulsion group tip speed	'Vtip n'	
propulsion group engine speed	'Nspec n'	

SET_vel, velocity specification:

- 'general' = general (use Vkts=horizontal, ROC, side)
- 'hover' = hover (zero velocity)
- 'vert' = hover or VROC (use ROC; Vkts=0, climb=0/+90/–90)
- 'right' = right sideward (use Vkts, ROC; side=90)
- 'left' = left sideward (use Vkts, ROC; side=–90)
- 'rear' = rearward (use Vkts, ROC, side=180)
- 'Vfwd' = general (use Vkts=forward velocity, ROC, side)
- 'Vmag' = general (use Vkts=velocity magnitude, ROC, side)
- 'climb' = general (use Vkts=velocity magnitude, climb, side)
- 'VNE' = never-exceed speed
- '+Mach' = use Mach not Vkts
- '+CAS' = Vkts is CAS not TAS
- '+IAS' = Vkts is IAS not TAS

velocities: forward $V_f = V_h \cos(\text{side})$, side $V_s = V_h \sin(\text{side})$, climb $V_c = V_h \tan(\text{climb})$

aircraft motion:
orientation velocity relative inertial axes defined by climb and sideslip angles (θ_V, ψ_V)
sideslip positive aircraft moving to right, climb positive aircraft moving up
specify horizontal velocity, vertical rate of climb, and sideslip angle
orientation body relative inertial axes defined by Euler angles, yaw/pitch/roll (ψ_F, θ_F, ϕ_F)
yaw positive to right, pitch positive nose up, roll positive to right
SET_PITCH and SET_roll, pitch and roll motion specification:
Aircraft values (perhaps function speed) or flight state input
initial values specified if motion is trim variable; otherwise fixed for flight state
SET_turn, bank angle and load factor in turn: use turn rate, load factor, or bank angle
$\tan(\text{roll}) = \sqrt{n^2 - 1}$ = (turn)V/g; calculated using input Vkts for flight speed
SET_pullup, load factor in pullup: use pullup rate or load factor
$n = 1 +$ (pullup)V/g; calculated using input Vkts for flight speed
SET_acc, linear acceleration: use acceleration or load factor

SET_atmos, atmosphere specification:
'std' = standard day at specified altitude (use altitude)
'polar' = polar day at specified altitude (use altitude)
'trop' = tropical day at specified altitude (use altitude)
'hot' = hot day at specified altitude (use altitude)
'xxx+dtemp' = specified altitude, plus temperature increment (use altitude, dtemp)
'xxx+temp' = specified altitude, and specified temperature (use altitude, temp)
'hot+table' = hot day table at specified altitude (use altitude)
'dens' = input density and temperature (use density, temp)
'input' = input density, speed of sound, and viscosity (use density, csound, viscosity)
'notair' = input, not air on earth (use density, csound, viscosity)

SET_GE: use HAGL; out-of-ground-effect (OGE) if rotor more than 1.5Diameter above ground
height rotor = landing gear above ground + hub above landing gear = HAGL + (WL_hub–WL_gear+d_gear)

STATE_LG: 'default' (based on retraction speed), 'extend', 'retract' (keyword = def, ext, ret)

STATE_control, aircraft control state: identifies control matrix
STATE_control=0 to use conversion schedule, STATE_control=n (1 to nstate_control) to use state#n
SET_control, control specification: Aircraft values (perhaps function speed) or flight state input
coll/latcyc/lngcyc/pedal/tilt specification and values put in SET_control and control, based on IDENT_control
initial values specified if control is trim variable; otherwise fixed for flight state
SET_control=0 to use Aircraft%cont and Aircraft%Vcont; 1 to use FltState%control
SET_tilt: 0 to use Aircraft%tilt and Aircraft%Vtilt; 1 to use FltState%tilt
2 to use conversion speeds Aircraft%Vconv_hover and Aircraft%Vconv_cruise

SET_cg, center of gravity position: input for this flight state; or
baseline cg position plus shift due to nacelle tilt, plus input cg increment

tip speed, engine, transmission: for each propulsion group
SET_Vtip, primary rotor tip speed: for primary rotor of propulsion group
'input' = use input Vtip for this flight state
'Mtip' = use input Mtip for this flight state
'Nrotor' = use input Nrotor (rpm) for this flight state
'ref' = use Vtip_ref (for drive state STATE_gear)
'speed' = use default Vtip(speed)
'conv' = use conversion schedule (Vtip_hover or Vtip_cruise)
'hover' = use default Vtip_hover = Vtip_ref(1)
'cruise', 'man', 'OEI', 'xmsn' = use default Vtip_cruise, Vtip_man, Vtip_oei, Vtip_xmsn
'mu' = use tip speed from μ (mu_Vtip)
'Mat' = use tip speed from M_{at} (Mat_Vtip)
'xxx+Mat' = for tip speed limited by M_{at} (Mat_Vtip)
'xxx+diam' = for variable diameter rotor, scale $V_{\rm tip}$ with radius ratio
without rotors, specify engine group speed by SET_Vtip='input' (use input Nspec) or 'ref'
STATE_gear, drive system state: identifies gear ratio set for multiple speed transmissions
state=0 to use conversion schedule, state=n (1 to nGear) to use gear ratio #n
drive system rating: match rating designation in propulsion group; blank for same as rating of first engine group
rating_ds='speed' to use schedule with speed
if Propulsion%nrate_ds≤ 1, drive system rating not used
fTorque reduces drive system torque limit (fTorque = 0. to 1.; > 1 is an acceptable input)
SET_Plimit: usually should not be applied for flight conditions and mission segments that size transmission

engine rating: match rating designation in engine model; e.g. 'ERP','MRP','IRP','MCP'
or rating='idle' or rating='takeoff'
fPower reduces engine group power available (fPower = 0. to 1.; > 1 is an acceptable input)
the engine model gives the power available, accounting for installation losses and mechanical limits
then the power available is reduced by the factor fPower
next torque limits are applied (unless SET_Plimit=off), first engine shaft limit and then drive system limit
for SET_GW='maxP' or 'maxPQ' (flight condition or mission), the gross weight is determined
such that $P_{reqPG} = fP_{avPG} + d$
either fPower or fPav can be used to reduce the available power
with identical results, unless the engine group is operating at a torque limit
nEngInop, number inoperative engines: 1 for one engine inoperative (OEI), maximum nEngine

SET_Preq: distribution of propulsion group power required among engine groups
distributed (SET_Preq=1): P_{reqEG} from P_{reqPG}, proportional P_{eng}
except for rotor reaction drive, P_{reqEG} from power needed to supply reaction force
and for fuselage or wing flow control, P_{reqEG} from power needed to supply momentum flux
fixed options use engine group amplitude control variable A, for each operable engine
engine group that consumes shaft power (generator or compressor) only uses fixed option
engine group that produces no shaft power (converted to turbo jet or reaction drive) only uses fixed option
EngineGroup%SET_Power, fPsize defines power distribution for sizing

jet rating: match rating designation in jet model; or rating_jet='idle' or rating_jet='takeoff'
fThrust reduces jet group thrust available (fThrust = 0 to 1; > 1 is an acceptable input)
nJetInop, number inoperative jets: 1 for one jet inoperative (OEI), maximum nJet
SET_Jreq: fixed options use jet group amplitude control variable A, for each operable jet
from component (SET_Jreq=1): only for reaction drive or flow control, T_{reqJG} from required F_{Greq}

charger rating: match rating designation in charger model; or rating_charge='idle' or rating_charge='takeoff'
fCharge reduces charger group power available (fCharge = 0 to 1; > 1 is an acceptable input)
nChrgInop, number inoperative chargers: 1 for one charger inoperative (OEI), maximum nCharge
SET_Creq: use charge group amplitude control variable A, for each operable charger

STOP_rotor: only for stoppable rotor; if stopped, model sets KIND_control=1, MODEL_Ftpp=1, MODEL_Fpro=3

STATE_trim, aircraft trim state: match IDENT_trim, 'none' for no trim
identifies trim variables and quantities
ACTION='configuration' defines trim states with following identification:
IDENT_trim='free', 'symm', 'hover', 'thrust', 'rotor', 'windtunnel', 'power', 'ground', 'comp'
requirement for trim_target depends on designation of Aircraft%trim_quant

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parent	int	parent (1 SizeCond, 2 SizeMiss, 3 OffMiss, 4 PerfCond)
kMission	int	Mission number
kMissSeg	int	MissSeg number
kFltState	int	FltState number
kcol_out	int	performance output column
		Maximum effort
imax_quant(2)	int	quantity (MAX_QUANT_xxx)
imax_quantn(2)	int	quantity structure number
imax_isslope(2)	int	quantity is slope (maximize)
imax_var(2)	int	variable (MAX_VAR_xxx, or control number)
imax_varn(2)	int	variable structure number
		Specification
iSET_vel	int	velocity (SET_vel_xxx)
iSET_vel2	int	velocity (SET_vel2_TAS, SET_vel2_CAS, SET_vel2_Mach)
isSideward	int	sideward flight (1 for sideward flight)
iSET_atmos	int	atmosphere (SET_atmos_xxx)
iSTATE_LG	int	landing gear state (STATE_LG_default, extend, retract)
iSTATE_trim	int	aircraft trim state (number, 0 for no trim)
		Specification, each propulsion group
iSET_Vtip(npropmax)	int	rotor tip speed (SET_Vtip_input, Nrotor, ref, speed, conv, hover, cruise, man, OEI, xmsn, mu, Mat, Mtip)
iSET_Vtip_Mat(npropmax)	int	rotor tip speed limited by M_{at}
iSET_Vtip_VarDiam(npropmax)	int	rotor tip speed for variable diameter rotor (1 to scale $V_{\rm tip}$ with radius ratio)
iSETPmargin(npropmax)	int	power margin as quantity (2 maximum effort, 1 trim)
iSETQmargin(npropmax)	int	torque margin as quantity (2 maximum effort, 1 trim)
krate_ds(npropmax)	int	drive system rating number
xSET_Plimit(npropmax)	int	drive system limit (SET_Plimit, superseded for sizing by Propulsion%SET_Plimit_size)

		Specification
krate(nengmax)	int	engine rating number
krate_jet(njetmax)	int	jet rating number
krate_charge(nchrgmax)	int	charger rating number
iSETEmargin(nengmax)	int	power margin as quantity (1 trim)
iSETJmargin(njetmax)	int	jet thrust margin as quantity (2 maximum effort, 1 trim)
iSETCmargin(nchrgmax)	int	charger power margin as quantity (1 trim)
iSETBmargin(ntankmax)	int	battery power margin as quantity (2 maximum effort, 1 trim)
		Weight
GW	real	gross weight W_G
Wfuel_total	real	usable fuel weight W_{fuel}
Wfuel(ntankmax)	real	usable fuel weight
Wfuel_std(ntankmax)	real	standard tanks
Wfuel_aux(ntankmax)	real	auxiliary tanks
Wpayload	real	payload weight W_{pay}
Wpay_pass	real	passengers W_{pass}
Wpay_cargo	real	cargo W_{cargo}
Wpay_extload	real	external load $W_{\text{ext-load}}$
Wpay_ammo	real	ammunition W_{ammo}
Wpay_weapons	real	weapons W_{weapons}
Wpay_other	real	other W_{other}
WFixUL	real	fixed useful load W_{FUL}
dW_fixUL	real	fixed useful load increment (relative weight statement W_fixUL)
Wcrew	real	crew (replace weight statement W_fixUL_crew)
Wauxtank	real	auxiliary fuel tanks (replace weight statement W_fixUL_auxtank)
W_fixUL_other	real	other fixed useful load (replace weight statement W_fixUL_other)
Woful(10)	real	categories
Wequip	real	equipment increment (replace weight statement W_fixUL_equip)
Wfoldkit	real	folding kit (replace weight statement W_fixUL_foldkit)
Wextkit	real	wing extension kit (replace weight statement W_fixUL_extkit)
Wwingkit	real	wing kit (replace weight statement W_fixUL_wingkit)
Wotherkit	real	other kit (replace weight statement W_fixUL_otherkit)
WO	real	operating weight W_O
Ncrew	int	number of crew

Npass	int	number of passengers
Ncrew_seat	int	number of crew seats
Npass_seat	int	number of passenger seats
Efuel_total	real	usable fuel energy E_{fuel}
Efuel(ntankmax)	real	usable fuel energy
Efuel_std(ntankmax)	real	standard tanks
Efuel_aux(ntankmax)	real	auxiliary tanks
		Weight at mission segment start
GW_start	real	gross weight W_G
Wfuel_start(ntankmax)	real	usable fuel weight W_{fuel}
Wfuel_std_start(ntankmax)	real	standard tanks
Wfuel_aux_start(ntankmax)	real	auxiliary tanks
Efuel_start(ntankmax)	real	usable fuel energy E_{fuel}
Efuel_std_start(ntankmax)	real	standard tanks
Efuel_aux_start(ntankmax)	real	auxiliary tanks
zcg(3)	real	Center of gravity position
SLcg	real	stationline
BLcg	real	buttline
WLcg	real	waterline
		Moments of inertia
Ixx	real	I_{xx}
Iyy	real	I_{yy}
Izz	real	I_{zz}
Ixy	real	I_{xy}
Iyz	real	I_{yz}
Ixz	real	I_{xz}

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weight statement defines fixed useful load and operating weight for design configuration
so for flight state, additional fixed useful load = auxiliary fuel tank and kits and increments
gross weight = weight empty + useful load = operating weight + payload + usable fuel
useful load = fixed useful load + payload + usable fuel
operating weight = weight empty + fixed useful load

		Atmosphere
alt	real	altitude h
tmp	real	temperature τ
dtmp	real	temperature increment ΔT
sigma	real	density ratio ρ/ρ_0
theta	real	temperature ratio T/T_0
delta	real	pressure ratio p/p_0
kinvis	real	kinematic viscosity $\nu = \mu/\rho$
altdens	real	density altitude h_d
altpress	real	pressure altitude h_p
		Flight condition
radius(nrotormax)	real	rotor radius R
VNE	real	never-exceed speed V_{NE} (knots TAS)
		rotational speeds
Vtip_trim(nrotormax)	real	rotor tip speed ΩR
rpm_trim(nrotormax)	real	rotor rpm Ω
rN_trim_rotor(nrotormax)	real	rotor $\Omega/\Omega_{\text{ref}}$
N_trim(nengmax)	real	engine rpm N
rN_trim_eng(nengmax)	real	engine N/N_{spec}
rN_trim_ref(npropmax)	real	propulsion group reference speed ratio
		flight speed
speed	real	horizontal speed V_h (knots)
Vclimb	real	climb velocity V_c (ft/sec or m/sec)
side_trim	real	sideslip angle ψ_V (deg)
		derived
Vhoriz	real	horizontal velocity V_h (ft/sec or m/sec)
Mhoriz	real	horizontal Mach number V_h/c_s
climb_trim	real	climb angle θ_V (deg)
Vside	real	sideward velocity V_s (ft/sec or m/sec)
Vmag	real	velocity magnitude $\|V\|$
Vfwd	real	forward velocity V_f (ft/sec or m/sec)
VCAS	real	calibrated airspeed V_{cal} (knots) ($V\sqrt{\sigma}f(\delta, M)$)
VIAS	real	indicated airspeed V_{ind} (knots)
VAC(3)	real	velocity v_{AC} in F axes

ed(3)	real	drag vector, $-v_{AC}/\lvert v_{AC}\rvert$ in F axes
qAC	real	dynamic pressure q_{AC}
Wind	real	headwind V_w (knots)
groundspeed	real	ground speed $V_g = V_h - V_w$ (knots)
		angular velocity
turn_trim	real	turn $\dot\psi_F$ (yaw rate)
pullup_trim	real	pullup $\dot\theta_F$ (pitch rate)
turnRadius	real	turn radius R_T
wAC(3)	real	ω_{AC} in F axes
		acceleration
aAC(3)	real	a_{AC} in F axes (linear)
nAC(3)	real	load factor n_{AC} (linear acc and angular rate)
KIND_alpha	int	angle of attack and sideslip angle representation (1 conventional, 2 reversed)
		orientation of body axes relative inertial axes
pitch_trim	real	pitch angle θ_F (deg)
roll_trim	real	roll angle ϕ_F (deg)
		rotation matrices
CFI(3,3)	real	C^{FI}, velocity axes relative inertial axes
CVI(3,3)	real	C^{VI}, body axes relative inertial axes
CFV(3,3)	real	C^{FV}, body axes relative velocity axes
control_trim(ncontmax)	real	aircraft controls
Nauxtank(nauxtankmax,ntankmax)		
	int	number of auxiliary fuel tanks N_{auxtank} (each aux tank size), from FltCond or MissSeg
SET_extkit(nwingmax)	int	wing extension kit on aircraft (0 none, 1 present)
SET_wingkit(nwingmax)	int	wing kit on aircraft (0 none, 1 present)
Wfuel_cap(ntankmax)	real	total fuel capacity $W_{\text{fuel-cap}}$, including auxiliary tanks
Efuel_cap(ntankmax)	real	total fuel capacity $E_{\text{fuel-cap}}$, including auxiliary tanks
slope_ground	real	slope of ground γ_G (+uphill; deg), from MissSeg
SET_sweep	int	parameter sweep, from FltCond

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angle of attack and sideslip angle representation: from Aircraft and isSideward

orientation body relative inertial axes defined by Euler angles, with yaw/pitch/roll sequence $(\psi_F, \theta_F, \phi_F)$
yaw positive to right, pitch positive nose up, roll positive to right
$C^{FI} = X_{\text{roll}} Y_{\text{pitch}} Z_{\text{yaw}}$, yaw angle = (turn)*time
orientation velocity relative inertial axes defined by climb and sideslip angles (θ_V, ψ_V)
sideslip positive aircraft moving to right, climb positive aircraft moving up
$C^{VI} = Y_{\text{climb}} Z_{\text{side}} Z_{\text{yaw}}$
orientation body relative velocity axes: $C^{FV} = X_{\text{roll}} Y_{\text{pitch}} Z_{-\text{side}} Y_{-\text{climb}}$

		Trim (last)
istrimconv	int	converged (0 not)
count_trim	int	number of iterations
error_trim(mtrimmax)	real	error ratio
resid_trim(mtrimmax)	real	residual (difference after one trim iteration)
gain_trim(mtrimmax,mtrimmax)	real	gain matrix
		Maximum effort (principal iteration, 99% range iteration; inner, outer loops)
isflyconv(2,2)	int	converged (0 not)
count_fly(2,2)	int	number of iterations
error_fly(2,2)	real	error ratio
isSwitched(2)	int	quantity switched (1 P margin, 2 Q margin, 3 both)
		Maximum gross weight (flight condition or mission takeoff)
ismaxgwconv	int	converged (0 not)
count_maxgw	int	number of iterations
error_maxgw	real	error ratio
		Rotor flap equation (all converged or any not converged)
isrotorconv	int	converged (0 not, –1 no iteration)
		Solution state
count_control	int	count of solution (0 at start, get aircraft controls)
trim_deriv_exist	int	trim derivative matrix exist (0 for not)

		Loads
		forces (F axes, about cg)
Faero(3)	real	aerodynamic $F^F_{\rm aero}$ (fuselage, rotor, wing, tail, tank, engine, jet, charger)
Frotor(3)	real	rotor $F^F_{\rm rotor}$
Ftank(3)	real	fuel tanks $F^F_{\rm tank}$
Fengine(3)	real	engine groups $F^F_{\rm eng}$ (jet thrust, momentum drag)
Fjet(3)	real	jet groups $F^F_{\rm jet}$
Fchrg(3)	real	charge groups $F^F_{\rm charge}$
Fgrav(3)	real	gravitational $F^F_{\rm grav}$
Finertia(3)	real	inertial $F^F_{\rm inertial}$ (turn)
		moments (F axes, about cg)
Maero(3)	real	aerodynamic $M^F_{\rm aero}$ (fuselage, rotor, wing, tail, tank, engine, jet, charger)
Mrotor(3)	real	rotor $M^F_{\rm rotor}$
Mtank(3)	real	fuel tanks $M^F_{\rm tank}$
Mengine(3)	real	engine groups $M^F_{\rm engine}$ (jet thrust, momentum drag)
Mjet(3)	real	jet groups $M^F_{\rm jet}$
Mchrg(3)	real	charge groups $M^F_{\rm charge}$
Minertia(3)	real	inertial $M^F_{\rm inertial}$ (turn)
Ftotal(3)	real	total force (F axes, about cg); $F + F_{\rm grav} - F_{\rm inertia}$
Mtotal(3)	real	total moment (F axes, about cg); $M - M_{\rm inertia}$
Download	real	download, aero F_z (I axes); set to 0 if V>10 knots
Thrust	real	rotor thrust, rotor $-F_z$ (I axes; sum Fvert)
DLoT	real	download/thrust DL/T
DLoW	real	download/weight DL/W
diskloadT	real	aircraft disk loading $T/A_{\rm ref}$ (lb/ft^2 or N/m^2)
diskloadW	real	aircraft disk loading $W_G/A_{\rm ref}$ (lb/ft^2 or N/m^2)
Aref	real	reference rotor area $A_{\rm ref} = \sum f_A A$
		Aircraft performance
		power
Preq	real	power required P_{req} (engine groups)
Pmargin	real	power margin, $\min(P_{av} - P_{req})$ (propulsion groups and converted engine groups)
Qmargin	real	torque margin, $\min(P_{\rm limit} - P_{req})$
exceedP	int	exceed power available: any propulsion group $P_{reqPG} > (1+\epsilon)P_{avPG}$
exceedQ	int	exceed torque available: any propulsion group $P_{reqPG} > (1+\epsilon)P_{DS{\rm limit}}$

		thrust
Tjet	real	thrust required T_{jet} (jet groups)
Jmargin	real	jet thrust margin, $\min(T_{av} - T_{req})$
exceedJ	int	exceed jet thrust available: any jet group $T_{reqJG} > (1+\epsilon)T_{avJG}$
		charging
Pchrg	real	power required P_{chrg} (charge groups)
Cmargin	real	charger power margin, $\min(P_{av} - P_{req})$
exceedC	int	exceed charger power available: any charge group $P_{reqCG} > (1+\epsilon)P_{avCG}$
Pequiv	real	equivalent aircraft power required $P = P_{req} + VT_{\text{jet}}$
Pclimb	real	climb power, $V_{\text{climb}}W$
fuelflow(ntankmax)	real	fuel flow $\dot{w}$
fuelflow_total	real	total fuel flow $\dot{w}$
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\text{equiv}}$, from energy flow
energyflow(ntankmax)	real	energy flow $\dot{E}$
energyflow_total	real	total energy flow $\dot{E}$
exceedWf	int	exceed fuel capacity: $W_{\text{fuel}} > (1+\epsilon)W_{\text{fuel-cap}}$ or $E_{\text{fuel}} > (1+\epsilon)E_{\text{fuel-cap}}$
		battery
Bmargin	real	battery power margin, $\min(P_{max} - \lvert\dot{E}_{\text{batt}}\rvert)$ (MJ/hr)
exceedB	int	exceed battery power: any fuel tank $\lvert\dot{E}_{\text{batt}}\rvert > (1+\epsilon)P_{\text{max}}$
sfc	real	sfc, $\dot{w}_{\text{equiv}}/P_{\text{equiv}}$ (lb/hp-hr or kg/kW-hr)
efficiency	real	efficiency, $P_{\text{equiv}}/\dot{E}$
spec_range	real	specific range, $V/\dot{w}_{\text{equiv}}$ (nm/lb or nm/kg)
spec_rangeE	real	specific range, $V/\dot{E}$ (nm/MJ)
		Performance indices
FM	real	aircraft figure of merit $FM = W\sqrt{W/(2\rho A_{\text{ref}})}/P$
LoDe	real	aircraft effective lift-to-drag ratio $L/D_e = WV/P$
Drage	real	aircraft effective drag $D_e = P/V$
DragAC	real	aircraft drag D_{AC}
DoQAC	real	aircraft drag area $D/q = D_{AC}/q_{AC}$; set to 0 if V<10 knots
WoP	real	power loading W/P
range_onepcW	real	range for fuel=1%GW (nm)
fuel_eff	real	fuel efficiency $e = W_{\text{pay}}V/\dot{w}_{\text{equiv}}$ (ton-nm/lb or ton-nm/kg)
productivity	real	productivity $p = W_{\text{pay}}V/W_O$ (ton-kt/lb or ton-kt/kg)

		Operating size
length_op	real	length
width_op	real	width
area_op	real	area

Chapter 21

Structure: FltFuse

Variable	Type	Description	Default
		Flight State - Fuselage	
		controls	
flow	real	momentum coefficient C_μ	
		aerodynamics	
VintR(3,nrotormax)	real	interference velocity v_{int}^F, from rotors (F axes)	
Vaero(3)	real	total velocity relative air v^F (F axes)	
VB(3)	real	total velocity relative air v^B (B axes)	
alpha	real	angle of attack α (deg)	
beta	real	sideslip angle β (deg)	
CBA(3,3)	real	C^{BA}	
Vmag	real	velocity magnitude	
q	real	dynamic pressure	
FGreq	real	flow control momentum flux required $F_{G\text{req}}$	
PEGreq	real	engine group power required to supply $F_{G\text{req}}$	
DoQ_pay	real	payload D/q	
DoQ_cont	real	contingency D/q	
CL	real	lift coefficient C_L	
CM	real	pitch moment coefficient C_M	
CD	real	drag coefficient C_D	
CY	real	side force coefficient C_Y	
CN	real	yaw moment coefficient C_N	
L	real	lift	
M	real	pitch moment	
D	real	drag	
Y	real	side force	
N	real	yaw moment	
		loads	
Faero(3)	real	aerodynamic force F_{aero}^F (F axes, about cg)	

Maero(3)	real	aerodynamic moment M^F_{aero} (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\text{aero}}$
Download	real	download, aero F_z (I axes)

Chapter 22

Structure: FltGear

Variable	Type	Description	Default
		Flight State - Landing Gear	
		aerodynamics	
iSTATE_LG	int	landing gear state (STATE_LG_extended, retracted)	
Vaero(3)	real	total velocity relative air v^F (F axes)	
Vmag	real	velocity magnitude	
q	real	dynamic pressure	
ed(3)	real	drag vector, $-v/\|v\|$ in F axes	
Faero(3)	real	aerodynamic force $F^F_{\rm aero}$ (F axes, about cg)	
Maero(3)	real	aerodynamic moment $M^F_{\rm aero}$ (F axes, about cg)	
Drag	real	drag $e_d^T F^F_{\rm aero}$	
Download	real	download, aero F_z (I axes)	

Chapter 23

Structure: FltRotor

Variable	Type	Description	Default
		Flight State - Rotor	
		control mode	
KIND_control_coll	int	collective control mode (1 thrust command, 2 pitch command)	
KIND_control_cyc	int	cyclic control mode (1 TPP command, 2 NFP command)	
Scoll	real	collective T matrix scale factor S $(1, a/6, \rho V_{\rm tip}^2 A_{\rm blade} a/6)$	
Scyc	real	cyclic T matrix scale factor S (–1 TPP command, 1 NFP command)	
		controls	
coll	real	collective	
lngcyc	real	longitudinal cyclic	
latcyc	real	lateral cyclic	
incid	real	incidence	
cant	real	cant	
diam	real	diameter	
fgear	real	gear ratio factor	
Freact	real	reaction drive net force $F_{\rm react}$	
		geometry	
Ccont(3,3)	real	shaft control, $C_{\rm cont}$	
CSF(3,3)	real	shaft relative airframe, C^{SF}	
zhub(3)	real	hub position, $z_{\rm hub}$	
zpylon(3)	real	pylon position, $z_{\rm pylon}$	
znac(3)	real	nacelle cg position, $z_{\rm nac}$	
CBF(3,3)	real	pylon relative airframe, C^{BF}	
		condition	
radius	real	radius R	
Vtip	real	tip speed $V_{\rm tip} = \Omega R$	
Omega	real	rotational speed Ω	
Mtip	real	tip Mach number $M_{\rm tip}$	
Mat	real	maximum Mach number M_{at} (advancing tip or helical)	

sigma	real	solidity σ (thrust weighted)
gamma	real	Lock number γ
Iblade	real	blade moment of inertia I_{blade}
flapfreq	real	flap frequency ν
conefreq	real	coning frequency ν
Khub	real	hub stiffness K_{hub}
		performance
		shaft axis loads
T	real	thrust
H	real	drag force
Y	real	side force
Mx	real	roll moment
My	real	pitch moment
Q	real	torque
CT	real	thrust coefficient C_T
CH	real	drag force coefficient C_H
CY	real	side force coefficient C_Y
CMx	real	roll moment coefficient C_{Mx}
CMy	real	pitch moment coefficient C_{My}
CQ	real	torque coefficient C_Q
		control and motion
theta75	real	collective pitch $\theta_{0.75}$ (0.75R)
thetas	real	longitudinal cyclic pitch θ_s
thetac	real	lateral cyclic pitch θ_c
beta0	real	coning β_0
betac	real	longitudinal flapping β_c
betas	real	lateral flapping β_s
lambda0	real	inflow $\lambda_0 = \kappa\lambda_i$
CPS(3,3)	real	tip-path plane relative shaft, C^{PS}
		velocity and inflow
VoVtip	real	V/V_{tip}
VF(3)	real	total velocity relative air v^F (F axes)
VS(3)	real	total velocity relative air v^S (S axes)
mux	real	μ_x

muy	real	μ_y
muz	real	μ_z
omegaS(3)	real	angular velocity ω^S (S axes)
dax	real	$\dot\alpha_x$
day	real	$\dot\alpha_y$
mu	real	$\mu = \sqrt{\mu_x^2 + \mu_y^2}$
alphas	real	$\alpha = \tan^{-1}(\mu_z/\mu)$
fDuctA	real	ducted fan area ratio f_A
fDuctT	real	ducted fan thrust ratio f_T
fDuctW	real	ducted fan far wake ratio f_W
fDuctD	real	ducted fan power ratio $f_D = f_W/2\eta_D$
zg	real	height rotor hub above ground, z_g/D
zge	real	effective height, $z_g C_g/(D\cos\epsilon)$
fg	real	ground effect inflow ratio $f_g = P/P_\infty$
kappag	real	ground effect thrust ratio $\kappa_g = T/T_\infty$
CTe	real	C_T for inflow solution
lambdah	real	reference $\lambda_h = \sqrt{C_T/2}$
lambda_ideal	real	ideal induced velocity λ_i
CPideal	real	ideal induced power $C_{P\text{ideal}} = C_T\lambda_i$
kappax	real	inflow gradient κ_x
kappay	real	inflow gradient κ_y
kappam	real	inflow gradient $\kappa_m = (\sigma a/8) f_m/U$
diskload	real	disk loading T/A (lb/ft^2 or N/m^2)
CTs	real	thrust coefficient/solidity, $\lvert C_T/\sigma\rvert$
FPpro	real	profile power factor F_P
FHpro	real	profile drag factor F_H
VintWn(3,nwingmax)	real	interference velocity v_{int}^F from wings, normal (F axes)
VintWp(3,nwingmax)	real	interference velocity v_{int}^F from wings, inplane (F axes)
		inplane forces
CHtpp	real	drag force C_H, tpp
CYtpp	real	side force C_Y, tpp
CHo	real	drag force C_H, profile
CYo	real	side force C_Y, profile
fB	real	blockage factor $f_B = \Delta T/T = B f_\mu f_z$

fDL	real	download factor $f_{DL} = 1/(1 - \Delta T/T) = 1/(1 - DL\, f_\mu f_z)$
		rotor flap equations
isrotorconv	int	converged (0 not, –1 no iteration)
count_rotor	int	iteration count
error_rotor(3)	real	error ratio (E_t, E_c, E_s)
resid_rotor(3)	real	residual (E_t, E_c, E_s)
rotor_deriv_exist	int	rotor derivative matrix exist (0 for not)
		loads
Frotor(3)	real	rotor force $F^F_{\rm rotor}$ (F axes, about cg)
Mrotor(3)	real	rotor moment $M^F_{\rm rotor}$ (F axes, about cg)
L	real	lift (wind axis)
X	real	drag (wind axis)
CL	real	lift coefficient C_L
CX	real	drag coefficient C_X
Fvert	real	vertical force (inertia axes)
CTs_rotor	real	rotor blade loading, $C_T/\sigma f_T$
CTs_steady	real	max C_T/σ (sustained)
CTs_tran	real	max C_T/σ (transient)
CTs_eqn	real	max C_T/σ (equation)
Tmargin_steady	real	thrust margin, $(C_T/\sigma)_{\rm max} - \lvert C_T/\sigma\rvert$ (sustained)
Tmargin_tran	real	thrust margin, $(C_T/\sigma)_{\rm max} - \lvert C_T/\sigma\rvert$ (transient)
Tmargin_eqn	real	thrust margin, $(C_T/\sigma)_{\rm max} - \lvert C_T/\sigma\rvert$ (equation)
Plimit_rs	real	drive system limit $P_{RS{\rm limit}}$ (at rpm_trim and rating_ds)
Qmargin_rs	real	torque margin, $P_{RS{\rm limit}} - P$
exceedQ_rs	int	exceed torque available: $P > (1+\epsilon)P_{RS{\rm limit}}$
		power
P	real	rotor power P
Pind	real	induced power P_i
Ppro	real	profile power P_o
Ppar	real	parasite power P_p
Pw	real	wing interference power P_w
Pd	real	propulsive force efficiency power P_d
Pv	real	climb efficient power P_v
CP	real	rotor power coefficient C_P

CPind	real	induced power coefficient C_{Pi}
CPpro	real	profile power coefficient C_{Po}
CPpar	real	parasite power coefficient C_{Pp}
CPw	real	wing interference power coefficient P_w
CPd	real	propulsive force efficiency power coefficient P_d
CPv	real	climb efficient power coefficient P_v
lambda	real	induced velocity λ
lambdat	real	wing interference velocity $\lambda_t = C_{Pw}/C_F$
Ki	real	induced power factor κ
cdmean	real	mean drag coefficient $c_{d\text{mean}}$
cdmean_basic	real	mean drag coefficient, basic (without TECH_drag or Re scale)
cdmean_stall	real	mean drag coefficient, stall (without TECH_drag or Re scale)
cdmean_comp	real	mean drag coefficient, compressible (without TECH_drag or Re scale)
cdmean_table	real	mean drag coefficient, table term
FM	real	hover figure of merit, $T f_D v/P$
etaprop	real	propulsive efficiency, TV/P
etamom	real	momentum efficiency, $T(V + f_D v)/P$
CDe	real	effective drag, $(C_{Pi} + C_{Po})/(V/V_{\text{tip}})$
LoDe	real	effective lift-to-drag, C_L/C_{De}
		shaft power and reaction drive
Pshaft	real	shaft power P_{shaft}
Preact	real	reaction drive power $P_{\text{react}} = \Omega r_{\text{react}} F_{\text{react}}$
rOmegareact	real	blade velocity Ωr_{react}
mdotreact	real	mass flow $\dot{m}_{\text{react}}$
STreact	real	specific thrust $ST = F_{G\text{req}}/\dot{m}_{\text{react}}$
FGreq	real	gross thrust (momentum flux) required $F_{G\text{req}} = F_{\text{react}} + \dot{m}_{\text{react}} \Omega r_{\text{react}}$
PEGreq	real	engine group power required to supply $F_{G\text{req}}$
		aerodynamics
		hub
Vaero_hub(3)	real	total velocity relative air v^F (F axes)
Vmag_hub	real	velocity magnitude
q_hub	real	dynamic pressure
ed_hub(3)	real	drag vector, $-v/\lvert v\rvert$ in F axes
VB_hub(3)	real	total velocity relative air v^B (B axes)

alpha_hub	real	angle of attack α (deg)
		pylon
Vaero_pylon(3)	real	total velocity relative air v^F (F axes)
Vmag_pylon	real	velocity magnitude
q_pylon	real	dynamic pressure
ed_pylon(3)	real	drag vector, $-v/\|v\|$ in F axes
VB_pylon(3)	real	total velocity relative air v^B (B axes)
alpha_pylon	real	angle of attack α (deg)
CDhub	real	drag coefficient, hub $C_{D\text{hub}}$
CDpylon	real	drag coefficient, pylon $C_{D\text{pylon}}$
CDduct	real	drag coefficient, duct $C_{D\text{duct}}$
CDspin	real	drag coefficient, spinner $C_{D\text{spin}}$
CDbldstop	real	drag coefficient, stopped blade $C_{D\text{blade}-\text{stop}}$
Dhub	real	drag, hub D_{hub}
Dpylon	real	drag, pylon D_{pylon}
Dduct	real	drag, duct D_{duct}
Dspin	real	drag, spinner D_{spin}
Dbldstop	real	drag, stopped blade $D_{\text{blade}-\text{stop}}$
		loads
Faero(3)	real	aerodynamic force F_{aero}^F (F axes, about cg)
Maero(3)	real	aerodynamic moment M_{aero}^F (F axes, about cg)
Drag	real	drag $e_d^T F_{\text{aero}}^F$
Download	real	download, aero F_z (I axes)
		interference
lambda_int	real	ideal induced velocity λ_i (from C_T)
vind(3)	real	induced velocity v_{ind}^F (F axes)
chi_wake	real	wake angle χ
Fint_fus	real	interference factor $f_W f_z f_r f_t$ at fuselage
Fint_wingLp(nwingmax,npanelmax)	real	interference factor $f_W f_z f_r f_t$ at wing, left panel
Fint_wingRp(nwingmax,npanelmax)	real	interference factor $f_W f_z f_r f_t$ at wing, right panel
Fint_tail(ntailmax)	real	interference factor $f_W f_z f_r f_t$ at tail
isInWake_fus	int	fuselage inside wake

isInWake_wingLp(nwingmax,npanelmax)		
	int	wing inside wake, left panel
isInWake_wingRp(nwingmax,npanelmax)		
	int	wing inside wake, right panel
isInWake_tail(ntailmax)	int	tail inside wake
ftwin	real	twin rotor factor f_t
Aint_wing(nwingmax)	real	induced power interference at wing $\alpha_{\rm int}$

Chapter 24

Structure: FltWing

Variable	Type	Description	Default
		Flight State - Wing	
		controls	
flap(npanelmax)	real	flap δ_F	
flaperon(npanelmax)	real	flaperon δ_f	
aileron(npanelmax)	real	aileron δ_a	
incid(npanelmax)	real	incidence i	
flow(npanelmax)	real	momentum coefficient C_μ	
		geometry	
zac(3)	real	aerodynamic center position, z_{ac}	
zcg(3)	real	center of gravity position, z_{cg}	
		aerodynamics	
VintR_Lp(3,nrotormax,npanelmax)	real	interference velocity $v_{\rm int}^F$ at left wing panel, from rotors (F axes)	
VintR_Rp(3,nrotormax,npanelmax)	real	interference velocity $v_{\rm int}^F$ at right wing panel, from rotors (F axes)	
VintR(3,nrotormax)	real	interference velocity $v_{\rm int}^F$ (panel area weighted), from rotors (F axes)	
VintW(3,nwingmax)	real	interference velocity $v_{\rm int}^F$, from other wings (F axes)	
AintW(nwingmax)	real	interference angle $\alpha_{\rm int}$, from other wings	
AintR(nrotormax)	real	induced power interference $\alpha_{\rm int}$, from rotors	
		with mean interference	
Vaero(3)	real	total velocity relative air v^F (F axes)	
VB(3)	real	total velocity relative air v^B (B axes)	
alpha	real	angle of attack α (deg)	
beta	real	sideslip angle β (deg)	
CBA(3,3)	real	C^{BA}	
Vmag	real	velocity magnitude	
q	real	dynamic pressure	

alpha_int	real	angle of attack α, with interference (deg)
CDV	real	vertical drag coefficient C_{DV}
		left panel
Vaero_Lp(3,npanelmax)	real	total velocity relative air v^F (F axes)
VB_Lp(3,npanelmax)	real	total velocity relative air v^B (B axes)
alpha_Lp(npanelmax)	real	angle of attack α (deg)
beta_Lp(npanelmax)	real	sideslip angle β (deg)
CBA_Lp(3,3,npanelmax)	real	C^{BA}
Vmag_Lp(npanelmax)	real	velocity magnitude
q_Lp(npanelmax)	real	dynamic pressure
CL_Lp(npanelmax)	real	lift coefficient C_{Lp}
CDp_Lp(npanelmax)	real	drag coefficient, parasite C_{Dpp}
CM_Lp(npanelmax)	real	pitch moment coefficient C_{Mp}
CR_Lp(npanelmax)	real	roll moment coefficient $C_{\ell p}$
L_Lp(npanelmax)	real	lift
Dp_Lp(npanelmax)	real	drag, parasite
M_Lp(npanelmax)	real	pitch moment
R_Lp(npanelmax)	real	roll moment
		right panel
Vaero_Rp(3,npanelmax)	real	total velocity relative air v^F (F axes)
VB_Rp(3,npanelmax)	real	total velocity relative air v^B (B axes)
alpha_Rp(npanelmax)	real	angle of attack α (deg)
beta_Rp(npanelmax)	real	sideslip angle β (deg)
CBA_Rp(3,3,npanelmax)	real	C^{BA}
Vmag_Rp(npanelmax)	real	velocity magnitude
q_Rp(npanelmax)	real	dynamic pressure
CL_Rp(npanelmax)	real	lift coefficient C_{Lp}
CDp_Rp(npanelmax)	real	drag coefficient, parasite C_{Dpp}
CM_Rp(npanelmax)	real	pitch moment coefficient C_{Mp}
CR_Rp(npanelmax)	real	roll moment coefficient $C_{\ell p}$
L_Rp(npanelmax)	real	lift
Dp_Rp(npanelmax)	real	drag, parasite
M_Rp(npanelmax)	real	pitch moment
R_Rp(npanelmax)	real	roll moment

qS	real	qS (sum over panels)
qeff	real	$(qS)/S$ (weighted by panel area)
dCLda3D	real	compressible 3D lift curve slope $C_{L\alpha}$
AoA_max	real	$\alpha_{\max}$
CL	real	lift coefficient C_L
CDp	real	drag coefficient, parasite C_{Dp}
CDi	real	drag coefficient, induced C_{Di}
CM	real	pitch moment coefficient C_M
CR	real	roll moment coefficient C_ℓ
CLmax	real	maximum lift coefficient $C_{L\max}$
L	real	lift
Dp	real	drag, parasite
Di	real	drag, induced
D	real	drag
M	real	pitch moment
R	real	roll moment
Lmargin	real	stall margin, $C_{L\max} - C_L$
FGreq	real	flow control momentum flux required $F_{G\mathrm{req}}$ (all panels)
PEGreq	real	engine group power required to supply $F_{G\mathrm{req}}$ (all panels)
		loads
Faero(3)	real	aerodynamic force F^F_{aero} (F axes, about cg)
Maero(3)	real	aerodynamic moment M^F_{aero} (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\mathrm{aero}}$
Download	real	download, aero F_z (I axes)
		interference
Vint_tail(3,ntailmax)	real	velocity at tail v^F_{int} (F axes)
vind(3)	real	induced velocity v^F_{ind} (F axes)
Vint_wing(3,nwingmax)	real	velocity at other wing v^F_{int} (F axes)
Aint_wing(nwingmax)	real	angle at other wing ($\alpha_{\mathrm{int}} = v_{\mathrm{int}}/v^B = K_{\mathrm{int}} v_{\mathrm{ind}}/v^B$)
Vintn_rotor(3,nrotormax)	real	velocity at rotor v^F_{int}, normal (F axes)
Vintp_rotor(3,nrotormax)	real	velocity at rotor v^F_{int}, inplane (F axes)

Chapter 25

Structure: FltTail

Variable	Type	Description	Default
		Flight State - Tail	
		controls	
cont	real	control δ	
incid	real	incidence i	
		aerodynamics	
VintR(3,nrotormax)	real	interference velocity $v_{\rm int}^F$, from rotors (F axes)	
VintW(3,nwingmax)	real	interference velocity $v_{\rm int}^F$, from wings (W axes)	
Vaero(3)	real	total velocity relative air v^F (F axes)	
VB(3)	real	total velocity relative air v^B (B axes)	
alpha	real	angle of attack α (deg)	
beta	real	sideslip angle β (deg)	
CBA(3,3)	real	C^{BA}	
Vmag	real	velocity magnitude	
q	real	dynamic pressure	
dCLda3D	real	compressible 3D lift curve slope $C_{L\alpha}$	
AoA_max	real	$\alpha_{\rm max}$	
CL	real	lift coefficient C_L	
CDp	real	drag coefficient, parasite C_{Dp}	
CDi	real	drag coefficient, induced C_{Di}	
CLmax	real	maximum lift coefficient $C_{L\rm max}$	
L	real	lift	
D	real	drag	
		loads	
Faero(3)	real	aerodynamic force $F_{\rm aero}^F$ (F axes, about cg)	
Maero(3)	real	aerodynamic moment $M_{\rm aero}^F$ (F axes, about cg)	
Drag	real	drag $e_d^T F_{\rm aero}^F$	
Download	real	download, aero F_z (I axes)	

Chapter 26

Structure: FltTank

Variable	Type	Description	Default
		Flight State - Fuel Tank Systems	
		all tanks (standard plus auxiliary)	
Wfuel	real	usable fuel weight	
Efuel	real	usable fuel energy	
Wfuel_cap	real	fuel weight capacity	
Efuel_cap	real	fuel energy capacity	
rWfuel	real	fraction weight capacity	
rEfuel	real	fraction energy capacity = state-of-charge = 1 - depth-of-discharge	
		battery ($\dot{E} > 0$ discharge, $\dot{E} < 0$ charge; power and current positive)	
Pfuel_cap	real	power capacity $P_{\text{cap}} = x_{mbd} E_{\text{fuel-cap}} / (d_{\max} - d_{\min})$ (MJ/hr)	
state	int	state (1 discharging, -1 CC charge, -2 CV charge)	
dact	real	actual depth-of-discharge $d_{\text{act}} = d_{\min} + (d_{\max} - d_{\min}) d_{\text{use}}$	
x	real	current x (1/hr)	
xi	real	current $\xi = x/x_{mbd}$	
V	real	voltage V	
Edotcomp	real	component energy flow $\dot{E}_{\text{comp}}$ (MJ/hr)	
etabatt	real	battery efficiency η_{batt}	
Ploss	real	power loss P_{loss} (MJ/hr)	
etasys	real	system efficiency η_{sys}	
Edotbatt	real	battery energy flow $\dot{E}_{\text{batt}}$ (MJ/hr)	
dcrit	real	effective capacity factor d_{crit}	
Edoteff	real	effective energy flow $\dot{E}_{\text{eff}}$ (MJ/hr)	
xmax	real	maximum current $x_{\max}$ (1/hr)	
Pmax	real	maximum power (for $x_{\max}$) (MJ/hr)	
Bmargin	real	battery power margin $P_{\max} - \lvert\dot{E}_{\text{batt}}\rvert$ (MJ/hr)	
exceedB	int	exceed battery power: $\lvert\dot{E}_{\text{batt}}\rvert > (1+\epsilon) P_{\max}$	

		system losses
Peq	real	equipment power loss $P_{\rm eq}$ (hp or kW)
Pdist	real	distribution power loss $P_{\rm dist}$ (MJ/hr)
		thermal management system
Prej	real	battery rejected power $P_{\rm rej}$ (MJ/hr)
mdot	real	mass flow $\dot{m}$
FG	real	gross jet thrust F_G
FN	real	net jet thrust F_N
Fjet(3)	real	jet thrust force $F^F_{\rm jet}$ (F axes, about cg)
Mjet(3)	real	jet thrust moment $M^F_{\rm jet}$ (F axes, about cg)
PTMS	real	thermal management system loss $P_{\rm TMS}$ (MJ/hr)
fuelflow	real	fuel flow $\dot{w}$
energyflow	real	energy flow $\dot{E}$
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\rm equiv}$, from energy flow
		aerodynamics
Vaero(3)	real	total velocity relative air v^F (F axes)
Vmag	real	velocity magnitude
q	real	dynamic pressure
ed(3)	real	drag vector, $-v/\|v\|$ in F axes
Dcool	real	cooling drag D
DL	real	download, aero F_z (I axes)
		auxiliary tanks
Vaero_aux(3,nauxtankmax)	real	total velocity relative air v^F (F axes)
Vmag_aux(nauxtankmax)	real	velocity magnitude
q_aux(nauxtankmax)	real	dynamic pressure
ed_aux(3,nauxtankmax)	real	drag vector, $-v/\|v\|$ in F axes
D_aux(nauxtankmax)	real	drag D
DL_aux(nauxtankmax)	real	download, aero F_z (I axes)
		loads
Faero(3)	real	aerodynamic force $F^F_{\rm aero}$ (F axes, about cg)
Maero(3)	real	aerodynamic moment $M^F_{\rm aero}$ (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\rm aero}$
Download	real	download, aero F_z (I axes)

Chapter 27

Structure: FltProp

Variable	Type	Description	Default
		Flight State - Propulsion Group	
STATE_gear	int	drive system state	
		control	
DN_trim	real	rotational speed increment, primary rotor or primary engine (rpm)	
		power	
Pcomp	real	power required P_{comp}, all components	
Pcomp_rotor	real	rotor	
Pcomp_eng	real	engine groups	
Pxmsn	real	transmission losses P_{xmsn}	
Pacc	real	accessory power P_{acc}	
PreqPG	real	power required $P_{reqPG} = P_{\text{comp}} + P_{\text{xmsn}} + P_{\text{acc}}$, propulsion group	
PavPG	real	power available P_{avPG}, propulsion group (sum all engine groups producing shaft power)	
PavEIsum	real	engine installed power available P_{avEI} (sum all engine groups producing shaft power)	
PavEGsum	real	engine group power available P_{avEG} (sum all engine groups producing shaft power)	
Pratio	real	P_{reqPG}/P_{avPG}, propulsion group	
Plimit_ds	real	drive system limit $P_{DS\text{limit}}$ (at rpm_trim(primary) and rating_ds, including fTorque)	
atPlimit_ds	int	at drive system limit (P_{avPG} limited by $P_{DS\text{limit}}$)	
Qmargin_ds	real	torque margin, $P_{DS\text{limit}} - P_{reqPG}$	
Pmargin	real	power margin, $P_{avPG} - P_{reqPG}$	
exceedP	int	exceed power available: $P_{reqPG} > (1+\epsilon)P_{avPG}$	
exceedQ_ds	int	exceed torque available: $P_{reqPG} > (1+\epsilon)P_{DS\text{limit}}$	
Qmargin	real	torque margin, min(propulsion group, engine groups, rotors)	
exceedQ	int	exceed torque available: any propulsion group, engine groups, rotors	
		propulsion group engines	
fuelflow(ntankmax)	real	fuel flow $\dot{w}$	
fuelflow_total	real	total fuel flow $\dot{w}$	
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\text{equiv}}$, from energy flow	
energyflow(ntankmax)	real	energy flow $\dot{E}$	

energyflow_total	real	total energy flow $\dot{E}$
sfc	real	specific fuel consumption $\mathrm{sfc} = \dot{w}_{\mathrm{equiv}}/P_{req}$
Fprop(3)	real	jet thrust and momentum drag force F^F_{prop} (F axes, about cg)
Mprop(3)	real	jet thrust and momentum drag moment M^F_{prop} (F axes, about cg)
Faero(3)	real	aerodynamic force F^F_{aero} (F axes, about cg)
Maero(3)	real	aerodynamic moment M^F_{aero} (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\mathrm{aero}}$
Download	real	download, aero F_z (I axes)

Chapter 28

Structure: FltEngn

Variable	Type	Description	Default
		Flight State - Engine Group	
		controls	
amp	real	amplitude A	
mode	real	mode B	
incid	real	incidence i	
yaw	real	yaw ψ	
fgear	real	gear ratio factor f_{gear}	
		geometry	
CBF(3,3)	real	engine relative airframe, C^{BF}	
ef(3)	real	engine direction, e_f	
		engine	
Pq	real	uninstalled power required, P_q	
Plossq	real	installation loss P_{loss} or P_{TMS}	
etalossq	real	installation efficiency η_{loss}	
Preq_eng	real	installed power required, $P_{req-\text{eng}}$	
N_trim	real	engine rpm N	
mdot	real	mass flow $\dot{m}$	
wdot	real	fuel flow $\dot{w}$	
Edot	real	energy flow $\dot{E}$	
FG	real	gross installed jet thrust F_G	
Fmom	real	momentum thrust $F_{\text{mom}} = \dot{m}V$	
FGreq	real	gross thrust (momentum flux) required $F_{Greq} = F_{\text{react}} + \dot{m}_{\text{react}}\Omega r_{\text{react}}$ or flow control (all components)	
FGq	real	$F_{Gq} = F_{G\text{req}}/$(Nengine–NEngInOp)	
FN	real	net installed jet thrust F_N	
Daux	real	momentum drag of auxiliary air flow D_{aux}	
Pa	real	uninstalled power available, P_a	
Plossa	real	installation loss P_{loss} or P_{TMS}	

etalossa	real	installation efficiency η_{loss}
Pav_eng	real	installed power available, $P_{av-\text{eng}}$
Pmech	real	engine mechanical limit P_{mech} (at N_trim)
atPmech	int	at mechanical limit ($P_{av-\text{eng}}$ limited by P_{mech})
etamotor	real	motor/generator efficiency η_{motor}
Prej	real	motor/generator rejected power P_{rej} (hp or kW)
		engine group
ReactionMode	int	reaction drive mode (MODEL_engine_compreact or converted)
Converted	int	converted (KIND=RPTEM with mode=1; 0 shaft power, 1 reaction, 2 jet)
ProducePower	int	shaft power (0 consumed (generator or compressor), 1 produced)
Pcomp	real	component power P_{comp} (generator or compressor); (Nengine–NEngInOp)$P_q K_{ffd}$
Preq	real	power required P_{reqEG}
PavEI	real	engine installed power available P_{avEI}; (Nengine–NEngInOp)$P_{av-\text{eng}}$
Pav	real	power available, P_{avEG}; fPower(Nengine–NEngInOp)$P_{av-\text{eng}}$
Qreq	real	torque required Q_{req} (at N_trim)
Pratio	real	P_{reqEG}/P_{avEG}
Pmargin	real	power margin, $P_{avEG} - P_{reqEG}$
Plimit_es	real	drive system limit $P_{ES\text{limit}}$ (at N_trim and rating_ds)
atPlimit_es	int	at drive system limit (P_{avEG} limited by $P_{ES\text{limit}}$)
Qmargin_es	real	torque margin, $P_{ES\text{limit}} - P_{reqEG}$
exceedQ_es	int	exceed torque available: $P_{reqEG} > (1+\epsilon)P_{ES\text{limit}}$
Fmargin	real	momentum margin, $F_G - F_{Greq}$
exceedF	int	exceed momentum available: $F_{Greq} > (1+\epsilon)F_G$
fuelflow	real	fuel flow $\dot{w}$ (negative if generated)
energyflow	real	energy flow $\dot{E}$ (negative if generated)
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\text{equiv}}$, from energy flow
sfc	real	specific fuel consumption sfc $= \dot{w}_{\text{equiv}}/P_{req}$
FNEG	real	net installed jet thrust F_N
DauxEG	real	momentum drag of auxiliary air flow D_{aux}
Fjet(3)	real	jet thrust force F^F_{jet} (F axes, about cg)
Mjet(3)	real	jet thrust moment M^F_{jet} (F axes, about cg)
Faux(3)	real	momentum drag force F^F_{aux} (F axes, about cg)
Maux(3)	real	momentum drag moment M^F_{aux} (F axes, about cg)

		aerodynamics
Vaero(3)	real	total velocity relative air v^F (F axes)
Vmag	real	velocity magnitude
q	real	dynamic pressure
ed(3)	real	drag vector, $-v/\|v\|$ in F axes
VB(3)	real	total velocity relative air v^B (B axes)
alpha	real	angle of attack α (deg)
CD	real	drag coefficient C_D
D	real	drag
Dcool	real	cooling drag
		load
Faero(3)	real	aerodynamic force F_{aero}^F (F axes, about cg)
Maero(3)	real	aerodynamic moment M_{aero}^F (F axes, about cg)
Drag	real	drag $e_d^T F_{\text{aero}}^F$
Download	real	download, aero F_z (I axes)

Chapter 29

Structure: FltJet

Variable	Type	Description	Default
		Flight State - Jet Group	
		controls	
amp	real	amplitude A	
mode	real	mode B	
incid	real	incidence i	
yaw	real	yaw ψ	
		geometry	
CBF(3,3)	real	jet relative airframe, C^{BF}	
ef(3)	real	jet direction, e_f	
		jet	
Tq	real	uninstalled thrust required T_q	
Tlossq	real	installation loss T_{loss}	
etalossq	real	installation efficiency η_{loss}	
Treq_jet	real	installed thrust required $T_{req-\text{jet}}$	
mdot	real	mass flow $\dot{m}$	
wdot	real	fuel flow $\dot{w}$	
Edot	real	energy flow $\dot{E}$	
ST	real	specific thrust $ST = T_{Gq}/\dot{m}$	
FG	real	gross installed jet thrust F_G	
Fmom	real	momentum thrust $F_{\text{mom}} = \dot{m}(1+\beta)V$	
FGreq	real	gross thrust (momentum flux) required $F_{G\text{req}} = F_{\text{react}} + \dot{m}_{\text{react}}\Omega r_{\text{react}}$ or flow control (all components)	
FGq	real	$F_{Gq} = F_{G\text{req}}/$(Njet–NJetInOp)	
FN	real	net installed jet thrust F_N	
Daux	real	momentum drag of auxiliary air flow D_{aux}	
Ta	real	uninstalled thrust available T_a	
Tlossa	real	installation loss T_{loss}	
etalossa	real	installation efficiency η_{loss}	

Tav_jet	real	installed thrust available $T_{av-\rm jet}$
Tmech	real	jet mechanical limit $T_{\rm mech}$
atTmech	int	at mechanical limit ($T_{av-\rm jet}$ limited by $T_{\rm mech}$)
		jet group
ReactionMode	int	reaction drive mode (MODEL_jet_react or converted)
Converted	int	converted (RPJEM with mode=1; 0 jet, 1 reaction)
Treq	real	thrust required T_{reqJG}
TavJI	real	jet installed thrust available T_{avJI}; (Njet–NJetInOp)$T_{av-\rm jet}$
Tav	real	thrust available, T_{avJG}; fThrust(Njet–NJetInOp)$T_{av-\rm jet}$
Jratio	real	T_{reqJG}/T_{avJG}
Jmargin	real	thrust margin $T_{avJG} - T_{reqJG}$
exceedJ	int	exceed thrust available: $T_{reqJG} > (1+\epsilon)T_{avJG}$
Fmargin	real	momentum margin $F_G - F_{Greq}$
exceedF	int	exceed momentum available: $F_{Greq} > (1+\epsilon)F_G$
fuelflow	real	fuel flow $\dot{w}$ (negative if generated)
energyflow	real	energy flow $\dot{E}$ (negative if generated)
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\rm equiv}$, from energy flow
sfc	real	specific fuel consumption ${\rm sfc} = \dot{w}_{\rm equiv}/T_{req}$
FNJG	real	net installed jet thrust F_N
DauxJG	real	momentum drag of auxiliary air flow $D_{\rm aux}$
Fjet(3)	real	jet thrust force $F^F_{\rm jet}$ (F axes, about cg)
Mjet(3)	real	jet thrust moment $M^F_{\rm jet}$ (F axes, about cg)
Faux(3)	real	momentum drag force $F^F_{\rm aux}$ (F axes, about cg)
Maux(3)	real	momentum drag moment $M^F_{\rm aux}$ (F axes, about cg)
		loads
F(3)	real	force $F^F_{\rm jet}$ (F axes)
M(3)	real	moment $M^F_{\rm jet}$ (F axes)
		aerodynamics
Vaero(3)	real	total velocity relative air v^F (F axes)
Vmag	real	velocity magnitude
q	real	dynamic pressure
ed(3)	real	drag vector, $-v/|v|$ in F axes
VB(3)	real	total velocity relative air v^B (B axes)
alpha	real	angle of attack α (deg)

CD	real	drag coefficient C_D
D	real	drag
Dcool	real	cooling drag
		load
Faero(3)	real	aerodynamic force $F^F_{\rm aero}$ (F axes, about cg)
Maero(3)	real	aerodynamic moment $M^F_{\rm aero}$ (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\rm aero}$
Download	real	download, aero F_z (I axes)

Chapter 30

Structure: FltChrg

Variable	Type	Description	Default
		Flight State - Charge Group	
		controls	
amp	real	amplitude A	
mode	real	mode B	
incid	real	incidence i	
yaw	real	yaw ψ	
		geometry	
CBF(3,3)	real	charger relative airframe, C^{BF}	
ef(3)	real	charger direction, e_f	
		charger	
Pacell	real	power available $P_{av} = P_{\rm acell} = \dot{E}_{\rm acell}$	
Pqcell	real	cell power required $P_{q\rm cell} = \dot{E}_{q\rm cell}$	
Preq	real	installed power required $P_{req} = P_{reqCG}/$(Ncharge–NChrgInOp)	
		charger, fuel cell	
deltac	real	compressor pressure ratio δ_c	
iratio	real	power required current ratio i_q/i_d	
sfc_burn	real	cell specific fuel consumption $\dot{w}/P_{req}$	
mdot_burn	real	mass flow $\dot{m}$	
wdot_burn	real	fuel flow $\dot{w}$	
FG	real	gross installed jet thrust F_G	
Fmom	real	momentum thrust $F_{\rm mom}$	
FN	real	net installed jet thrust F_N	
Daux	real	momentum drag of auxiliary air flow $D_{\rm aux}$	
		charger, solar cell	
etachrg	real	charger efficiency $\eta_{\rm chrg}$	

		charge group
Pchrg	real	power required $P_{reqCG} = \dot{E}_{reqCG}$
Preqtotal	real	total cell power required $P_{req\text{total}}$; (Ncharge–NChrgInOp)$P_{q\text{cell}}$
PavCG	real	power available P_{avCG}; fCharge(Ncharge–NChrgInOp)P_{av}
Cratio	real	P_{reqCG}/P_{avCG}
Cmargin	real	power margin, $P_{avCG} - P_{reqCG}$
exceedC	int	exceed power available: $P_{reqCG} > (1+\epsilon)P_{avCG}$
energyflow	real	energy flow $\dot{E}$ (negative if generated)
fuelflow_equiv	real	equivalent fuel flow $\dot{w}_{\text{equiv}}$, from energy flow
		charge group, fuel cell
		fuel burn
fuelflow_burn	real	fuel flow $\dot{w}$
energyflow_burn	real	energy flow $\dot{E}$
fuelflow_equiv_burn	real	equivalent fuel flow $\dot{w}_{\text{equiv}}$, from energy flow
sfc	real	specific fuel consumption $\text{sfc} = \dot{w}_{\text{equiv}}/P_{req}$
FNCG	real	net installed jet thrust F_N
DauxCG	real	momentum drag of auxiliary air flow D_{aux}
Fjet(3)	real	jet thrust force F^F_{jet} (F axes, about cg)
Mjet(3)	real	jet thrust moment M^F_{jet} (F axes, about cg)
Faux(3)	real	momentum drag force F^F_{aux} (F axes, about cg)
Maux(3)	real	momentum drag moment M^F_{aux} (F axes, about cg)
		loads
F(3)	real	force F^F_{chrg} (F axes)
M(3)	real	moment M^F_{chrg} (F axes)
		aerodynamics
Vaero(3)	real	total velocity relative air v^F (F axes)
Vmag	real	velocity magnitude
q	real	dynamic pressure
ed(3)	real	drag vector, $-v/|v|$ in F axes
VB(3)	real	total velocity relative air v^B (B axes)
alpha	real	angle of attack α (deg)
CD	real	drag coefficient C_D
D	real	drag

Dcool	real	cooling drag
		load
Faero(3)	real	aerodynamic force $F^F_{\rm aero}$ (F axes, about cg)
Maero(3)	real	aerodynamic moment $M^F_{\rm aero}$ (F axes, about cg)
Drag	real	drag $e_d^T F^F_{\rm aero}$
Download	real	download, aero F_z (I axes)

Chapter 31

Structure: Solution

Variable	Type		Description	Default
		+	Solution Procedures	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Rotor	
		+	convergence control	
niter_rotor(nrotormax)	int	+	maximum number of iterations	40
toler_rotor(nrotormax)	real	+	tolerance (deg)	.01
relax_rotor(nrotormax)	real	+	relaxation factor	.5
deriv_rotor(nrotormax)	int	+	derivative (1 first order, 2 second order)	1
maxinc_rotor(nrotormax)	real	+	maximum increment amplitude (0. for no limit)	4.
trace_rotor(nrotormax)	int	+	trace iteration (0 for none)	0
		+	Trim	
		+	convergence control	
niter_trim	int	+	maximum number of iterations	40
toler_trim	real	+	tolerance (fraction reference)	.001
relax_trim	real	+	relaxation factor	.5
		+	perturbation identification of derivative matrix	
deriv_trim	int	+	perturbation (1 first order, 2 second order)	1
mpid_trim	int	+	number of iterations between identification (0 for never recalculated)	0
perturb_trim	real	+	variable perturbation amplitude (fraction reference)	.002
init_trim	int	+	reinitialize aircraft controls in maximum effort iteration (0 no, 1 force retrim)	0
start_trim	int	+	initialize controls from solution of previous case (0 no)	0
trace_trim	int	+	trace iteration (0 for none, 2 for component controls)	0

start_trim=1: initialize FltAircraft%control from FltAircraft%control_trim of previous case
require INIT_input=INIT_data=2 or read solution file; and same missions and conditions as previous case
requirements not checked

		+	Maximum effort	
method_fly	int	+	method (1 secant, 2 false position)	1
method_flymax	int	+	maximization method (1 secant, 2 false position, 3 golden section search, 4 curve fit)	3
		+	convergence control	
niter_fly	int	+	maximum number of iterations	80
toler_fly	real	+	tolerance (fraction reference)	.002
relax_fly	real	+	relaxation factor	.5
perturb_fly	real	+	variable perturbation amplitude (fraction reference)	.05
maxderiv_fly	real	+	maximum derivative amplitude (0. for no limit)	0.
maxinc_fly	real	+	maximum increment fraction (0. for no limit)	0.
rfit_fly	real	+	extent of curve fit (fraction maximum)	.98
nfit_fly	int	+	order of curve fit (2 quadradic, 3 cubic)	3
init_fly	int	+	reinitialize aircraft controls (0 no, 1 force retrim)	0
trace_fly	int	+	trace iteration (0 for none)	0
		+	Maximum gross weight (flight condition or mission takeoff)	
method_maxgw	int	+	method (1 secant, 2 false position)	1
		+	convergence control	
niter_maxgw	int	+	maximum number of iterations	40
toler_maxgw	real	+	tolerance (fraction reference)	.002
relax_maxgw	real	+	relaxation factor	.5
perturb_maxgw	real	+	variable perturbation amplitude (fraction reference)	.02
maxderiv_maxgw	real	+	maximum derivative amplitude (0. for no limit)	0.
maxinc_maxgw	real	+	maximum increment fraction (0. for no limit)	0.
trace_maxgw	int	+	trace iteration (0 for none)	0
		+	Mission	
		+	convergence control	
niter_miss	int	+	maximum number of iterations	40
toler_miss	real	+	tolerance (fraction reference)	.01
relax_miss	real	+	relaxation factor (mission fuel)	1.
relax_range	real	+	relaxation factor (range credit)	1.
relax_gw	real	+	relaxation factor (max takeoff GW)	1.
trace_miss	int	+	trace iteration (0 for none)	0

		+	Size aircraft	
		+	convergence control	
niter_size	int	+	maximum number of iterations (performance loop)	40
niter_param	int	+	maximum number of iterations (parameter loop)	40
toler_size	real	+	tolerance (fraction reference)	.01
		+	relaxation factors	
relax_size	real	+	power or radius	1.
relax_DGW	real	+	gross weight	1.
relax_xmsn	real	+	drive system limit	1.
relax_wmto	real	+	WMTO and SDGW	1.
relax_tank	real	+	fuel tank capacity	1.
relax_thrust	real	+	rotor thrust	1.
		+	maximum increment fraction (0. for no limit)	
maxinc_size	real	+	power or radius	0.
maxinc_DGW	real	+	gross weight	0.
maxinc_xmsn	real	+	drive system limit	0.
maxinc_wmto	real	+	WMTO and SDGW	0.
maxinc_tank	real	+	fuel tank capacity	0.
maxinc_thrust	real	+	rotor thrust	0.
trace_size	int	+	trace iteration (0 for none, 2 for power)	0

with niter_param=1, parameter iteration is part of performance loop (can be faster than niter_param $>$ 1)

		+	Case	
trace_case	int	+	trace operation (0 for none, 1 trace, 2 for all iterations)	1
trace_start	int	+	counter at start trace of iterations	0
trace_count	int		counter	

use trace_case=2 to identify point at which analysis diverges
counter written if trace_case=1 or 2; trace of iterations suppressed until counter $>$ trace_start
then turn on trace selectively for mission/segment/condition

		+	Flight condition and mission segment	
toler_check	real	+	check Preq, Qlimit, Wfuel (fraction reference)	.005
		+	Tolerance and perturbation scales	
KIND_Wscale	int	+	weight scale (1 design gross weight, 2 nominal C_T/σ)	1
KIND_Pscale	int	+	power scale (1 aircraft power, 2 derived from weight scale)	1
KIND_Lscale	int	+	length scale (1 rotor radius, 2 wing span, 3 fuselage length)	1
scaleRotor	int	+	rotor number	1
scaleWing	int	+	wing number	1
			Derived tolerance and perturbation scales	
Wscale	real		weight scale	
Pscale	real		power scale	
Lscale	real		length scale	
Ascale	real		angle scale	
Fscale	real		force scale	
Mscale	real		moment scale	
Vscale	real		horizontal velocity scale	
Rscale	real		vertical velocity scale	
Oscale	real		angular velocity scale	
Tscale	real		C_T/σ scale	
Cscale	real		C_L scale	
Hscale	real		altitude scale	
Gscale	real		acceleration scale	
Xscale	real		range scale	

		+	External solution procedure (0 for internal)	
SETextsol_size	int	+	size iteration	0
SETextsol_miss	int	+	mission iteration	0
SETextsol_trim	int	+	trim iteration	0
SETextsol_rotor	int	+	rotor iteration	0

---

for external solution procedure (SETextsol $= 1$), suppress iteration and calculate residual
the solution problem (such as size parameters, trim variables) must still be defined
residuals (and error ratios) are in structures SizeParam, MissParam, FltAircraft, FltRotor
with external solution for maximum gross weight or maximum effort, there is no residual; do not specify internal iteration

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Chapter 32

Structure: Cost

Variable	Type		Description	Default
		+	Cost	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Inflation	
MODEL_inf	int	+	model (1 only input factor, 2 CPI, 3 DoD)	3
year_inf	int	+	year for internal inflation factor	2018
inflation	real	+	inflation factor (per cent, relative 1994 or year_inf)	100.00
EXTRAP_inf	int	+	year beyond CPI/DoD table data (0 error, 1 extrapolate factor)	1

inflation: F_i multiplies airframe purchase price and maintenance cost
factor inflation always used, even with internal table
CPI or DoD table: $F_i = \text{inflation}\big(F_{\text{table}}(\text{year\_inf})/F_{\text{table}}(1994)\big)$
input factor: $F_i = \text{inflation}$ (relative 1994)
cost factors and rates include technology and inflation, correspond to year_inf

Variable	Type		Description	Default
		+	Cost	
MODEL_cost	int	+	model (0 none)	1
FuelPrice(ntankmax)	real	+	fuel price G_{fuel} ($/gallon or $/liter)	5.0
EnergyPrice(ntankmax)	real	+	energy price G_{energy} ($/MJ or $/kWh, Units_energy)	0.04
EnergyCredit(ntankmax)	real	+	credit for generated energy ($/MJ or $/kWh, Units_energy)	0.
Npass	int	+	number of passengers N_{pass}	100

equivalent energy price for fuel burned: $/MJ≅($/gal)/126.2 (based on 42.8 MJ/kg and 6.5 lb/gal of JP-4/JP-8)
EnergyCredit=0. if no credit for generated energy

		+	Direct Operating Cost	
BlockHours	real	+	available block hours per year B	3751.
NonFlightTime	real	+	non-flight time per trip T_{NF} (min)	12.
DepPeriod	real	+	depreciation period D (years)	15.
LoanPeriod	real	+	loan period L (years)	15.
IntRate	real	+	interest rate i (%)	8.
ResidValue	real	+	residual value V (%)	10.
Spares	real	+	spares per aircraft S (% purchase price)	25.
LoadFactor	real	+	passenger load factor (%)	75.
		+	Technology Factors	
TECH_cost_af	real	+	airframe χ_{AF}	0.87
TECH_cost_maint	real	+	maintenance χ_{maint}	1.0
TECH_cost_comp	real	+	components χ_{comp}	1.0
		+	CTM rotorcraft cost model	
		+	Purchase Price	
MODEL_aircraft	int	+	aircraft (1 rotorcraft, 2 turboprop airliner)	1
KIND_engine	int	+	engine (1 turbine, 2 piston)	1
fmotor	real	+	weighting factor for electric motor or generator	0.5
		+	airframe	
rComp	real	+	additional cost rate r_{comp} for composite construction ($/lb or $/kg)	0.
fWcomp_body	real	+	composite weight in body (fraction body weight)	0.
fWcomp_tail	real	+	composite weight in tail (fraction tail weight)	0.
fWcomp_pylon	real	+	composite weight in pylon (fraction pylon weight)	0.
fWcomp_wing	real	+	composite weight in wing (fraction wing weight)	0.
		+	systems (fixed useful load)	
rFCE	real	+	cost factor r_{FCE}, flight control electronics ($/lb or $/kg)	10000.
rMEP	real	+	cost factor r_{MEP}, mission equipment package ($/lb or $/kg)	10000.
rBatt	real	+	cost factor r_{batt}, battery ($/MJ or $/kWh, Units_energy)	50.

cost factors and rates include technology and inflation, correspond to year_inf
rComp negative for cost reduction

		+	Maintenance	
MODEL_maint	int	+	maintenance cost estimate (1 total only, 2 separate components)	2
rLabor	real	+	labor rate ($ per hour)	160.
MMHperFH	real	+	maintenance man hours per flight hour	0.
Mlabor	real	+	MMH/FH factor $M_{\rm labor}$	0.0017
Mparts	real	+	parts factor $M_{\rm parts}$	34.
Mengine	real	+	engine overhaul factor $M_{\rm engine}$	1.45
Mmajor	real	+	major periodic maintenance factor $M_{\rm major}$	18.
Mbatt	real	+	battery maintenance factor $M_{\rm batt}$ ($/MJ or $/kWh per hour, Units_energy)	.10

labor rate includes inflation, corresponds to year_inf
current best practice: Mlabor=0.0017, Mparts=34, Mengine=1.45, Mmajor=18
current average practice: Mlabor=0.0027, Mparts=56, Mengine=1.74, Mmajor=28

maintenance man hours per flight hour calculated from sum of fixed term (MMHperFH) and term scaling with weight empty (Mlabor)

		+	Direct Operating Cost	
MODEL_doc	int	+	crew+depreciation+insurance estimate (1 total only, 2 separate components)	2
Kcdi	real	+	crew+depreciation+insurance factor $K_{\rm cdi}$	1.0
Kcrew	real	+	crew cost factor $K_{\rm crew}$	1.0
Kins	real	+	insurance cost $K_{\rm ins}$ (fraction aircraft cost)	.0056
KETS	real	+	emissions trading scheme cost $K_{\rm ETS}$ ($/kg CO_2)	.02
		+	Scott rotorcraft component cost model	
		+	production	
year_proc	int	+	year of procurement (0 same as year_inf, not used if <1955)	0
Nprod	int	+	aircraft production number (0 not used)	0
Nlot	int	+	number aircraft in this production lot (0 not used)	0
Nprod_eng	int	+	engine production number (0 not used)	0

		+	systems	
drFCE	real	+	cost factor $\Delta r_{\rm FCE}$, additional flight control electronics ($/lb or $/kg)	0.
drMEP	real	+	cost factor $\Delta r_{\rm MEP}$, additional mission equipment package ($/lb or $/kg)	0.
		+	component cost models	
f_sec	real	+	fuselage, fraction of secondary fuselage weight	0.35
KIND_fuse_boom	int	+	fuselage, includes tail boom (0 not)	0
KIND_fuse_dev	int	+	fuselage, early LRIP of new design (0 not)	0
MODEL_eng	int	+	engine, turboshaft (0 not)	1
Kmotor	real	+	electric motor/generator cost $c = KP^X$, factor	0.2
Xmotor	real	+	electric motor/generator cost $c = KP^X$, exponent	1.0
Pr_avg	real	+	engine, stage-averaged compressor pressure ratio	1.6
TBO_eng	real	+	engine, time between overhaul (hours)	2000.
KIND_eng_mar	int	+	engine, marinized (0 not)	0
KIND_eng_FADEC	int	+	engine, FADEC equipped (0 not)	1
KIND_xmsn_rg	int	+	transmission, engine group includes reduction gearbox (0 direct drive)	0
KIND_xmsn_mar	int	+	transmission, marinized (0 not)	0
KIND_av_dev	int	+	avionics, early LRIP of new package (0 not)	0
KIND_av_UAV	int	+	avionics, unmanned medium to long endurance aircraft (0 not)	0
f_env	real	+	environmental group, fraction prime equipment cost	0.03
f_arm_furn_LH	real	+	armament provisions, furnishings, and load and handling groups, fraction fuselage cost	0.12
KIND_int_SE_prof	int	+	integration and assembly, systems engineering, and profit (1 government, 2 commercial)	1
f_int_SE_prof	real	+	integration and assembly, systems engineering, and profit (commercial), fraction prime equipment cost	0.25

Chapter 33

Structure: Emissions

Variable	Type		Description	Default
		+	Emissions	
title	c*100	+	title	
notes	c*1000	+	notes	
MODEL_emissions	int	+	Emissions model (0 none)	1
		+	Emissions Trading Scheme (ETS)	
Kfuel(ntankmax)	real	+	CO_2 emissions from fuel used, K_{fuel} (kg/kg)	3.75
Kenergy(ntankmax)	real	+	CO_2 emissions from energy used, K_{energy} (kg/MJ or kg/kWh, Units_energy)	0.14
		+	Average Temperature Response (ATR)	
H	real	+	aircraft operating lifetime H (yr)	30.
U	real	+	aircraft utilization rate U (missions/yr)	350.
r	real	+	ATR discount rate r	0.03
tmax	real	+	ATR integration period $t_{\max}$ (yr)	500.
		+	emission index (kg/kg)	
EI_CO2(ntankmax)	real	+	carbon dioxide, EI_{CO_2}	3.16
EI_H2O(ntankmax)	real	+	water vapor, $EI_{\text{H}_2\text{O}}$	1.26
EI_SO4(ntankmax)	real	+	sulphates, EI_{SO_4}	0.0002
EI_soot(ntankmax)	real	+	soot, EI_{soot}	0.00004
EI_NOx(ntankmax)	real	+	nitrogen oxides, EI_{NO_x}	0.01
MODEL_NOx(ntankmax)	int	+	turboshaft engine NOx emission model (0 input EI_{NO_x}, 1 DLR, 2 Swiss)	1
KIND_NOx(ntankmax)	int	+	model parameters (0 input, 1 low emissions, 2 high emissions)	1
KEI0(ntankmax)	real	+	DLR model, K_{EI0}	0.0036739
KEI1(ntankmax)	real	+	DLR model, K_{EI1}	0.00748
KEIs(ntankmax)	real	+	Swiss model, K_{EIs}	0.004
fAIC	real	+	aviation induced cloudiness factor, f_{AIC}	1.0
		+	energy emission factor (kg/MJ or kg/kWh, Units_energy)	
K_CO2(ntankmax)	real	+	carbon dioxide, K_{CO_2}	0.14
K_H2O(ntankmax)	real	+	water vapor, $K_{\text{H}_2\text{O}}$	0.

K_SO4(ntankmax)	real	+	sulphates, K_{SO_4}	0.
K_soot(ntankmax)	real	+	soot, K_{soot}	0.
K_NOx(ntankmax)	real	+	nitrogen oxides, K_{NO_x}	0.
SET_credit	int	+	Emissions credit for energy generated (0 for none)	1

EI default values are for turboshaft engine

emission index (EI and K_{fuel}) only used for tanks that store and use fuel as weight (SET_burn=1)
energy emission factor (K and K_{energy}) only used for tanks that store and use fuel as energy (SET_burn=2)

ATR discount rate: $r \geq 100000$ evaluated as $r = \infty$

		ATR factors
ZCO2	real	CO_2
ZNOx	real	NO_x (CH_4 and O_{3L})
Zs	real	short life
		turboshaft NO_x model
fPower(11,nengmax)	real	power factor, $P_q = f_P P_{to}$
wdot(11,nengmax)	real	fuel flow, $\dot{w}$

Chapter 34

Structure: Aircraft

Variable	Type		Description	Default
		+	Aircraft	
title	c*100	+	title	
notes	c*1000	+	notes	
config	c*16	+	Configuration	'helicopter'
RCconfig	int		configuration (RCconfig_rotorcraft, helicopter, tandem, coaxial, tiltrotor, compound, multicopter, airplane)	
nRotor_main	int		number of main rotors	

config: identifies rotorcraft configuration
config = 'rotorcraft', 'helicopter', 'tandem', 'coaxial', 'tiltrotor', 'compound', 'multicopter', 'airplane'

Variable	Type		Description	Default
		+	Aircraft Controls	
ncontrol	int	+	number of aircraft controls (maximum ncontmax)	4
IDENT_control(ncontmax)	c*16	+	labels of aircraft controls	
nstate_control	int	+	number of control states (maximum nstatemax)	1
			pilot's controls (control number)	
kcoll	int		collective stick	
klatcyc	int		lateral cyclic stick	
klngcyc	int		longitudinal stick	
kpedal	int		pedal	
ktilt	int		tilt	
		+	control values (function speed)	
nVcont(ncontmax)	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	
nVcoll	int	+	collective stick	0
nVlatcyc	int	+	lateral cyclic stick	0
nVlngcyc	int	+	longitudinal stick	0

nVpedal	int	+	pedal	0
nVtilt	int	+	tilt	0
cont(nvelmax,ncontmax)	real	+	values	
coll(nvelmax)	real	+	collective stick c_{AC0}	
latcyc(nvelmax)	real	+	lateral cyclic stick c_{ACc}	
lngcyc(nvelmax)	real	+	longitudinal cyclic stick c_{ACs}	
pedal(nvelmax)	real	+	pedal c_{ACp}	
tilt(nvelmax)	real	+	tilt $\alpha_{\rm tilt}$	
Vcont(nvelmax,ncontmax)	real	+	speeds (CAS or TAS)	
Vcoll(nvelmax)	real	+	collective stick	
Vlatcyc(nvelmax)	real	+	lateral cyclic stick	
Vlngcyc(nvelmax)	real	+	longitudinal cyclic stick	
Vpedal(nvelmax)	real	+	pedal	
Vtilt(nvelmax)	real	+	tilt	

---

control system: set of aircraft controls c_{AC} defined
    aircraft controls connected to individual controls of each component, $c = Tc_{AC} + c_0$
    for each component control, define matrix T (for each control state) and value c_0
        flight state specifies control state, or that control state obtained from conversion schedule
    c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
        use of component control c_0 can be suppressed for flight state using SET_comp_control
aircraft controls: identified by IDENT_control
    typical aircraft controls are pilot's controls; default IDENT_control='coll','latcyc','lngcyc','pedal','tilt'
    available for trim (flight state specifies trim option)
        initial values specified if control is trim variable; otherwise fixed for flight state
    each aircraft control can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
        coll/latcyc/lngcyc/pedal/tilt input put in appropriate nVcont-cont-Vcont, based on IDENT_control
    flight state input can override
    by connecting aircraft control to component control, flight state can specify component control value
sign conventions for pilot's controls: collective + up, lat cyclic + right, long cyclic + forward, pedal + nose right
    rotor controls are positive Fourier series, with azimuth measured in direction of rotation

---

		+	Aircraft Motion
		+	aircraft pitch angle θ_F
nVpitch	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)
pitch(nvelmax)	real	+	values
Vpitch(nvelmax)	real	+	speeds (CAS or TAS)
		+	aircraft roll angle ϕ_F
nVroll	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)
roll(nvelmax)	real	+	values
Vroll(nvelmax)	real	+	speeds (CAS or TAS)

---

aircraft motion
available for trim (depending on flight state)
each motion can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
flight state input can override; initial value if trim variable

---

		+	Conversion	
Vconv_hover	real	+	maximum speed for hover and helicopter mode (CAS or TAS)	
Vconv_cruise	real	+	minimum speed for cruise (CAS or TAS)	
		+	control state	
kcont_hover	int	+	hover and helicopter mode ($V \leq V_{\rm conv-hover}$)	1
kcont_conv	int	+	conversion mode ($V_{\rm conv-hover} < V < V_{\rm conv-cruise}$)	1
kcont_cruise	int	+	cruise mode ($V \geq V_{\rm conv-cruise}$)	1
		+	drive system state (each propulsion group)	
kgear_hover(npropmax)	int	+	hover and helicopter mode ($V \leq V_{\rm conv-hover}$)	1
kgear_conv(npropmax)	int	+	conversion mode ($V_{\rm conv-hover} < V < V_{\rm conv-cruise}$)	1
kgear_cruise(npropmax)	int	+	cruise mode ($V \geq V_{\rm conv-cruise}$)	1

---

conversion control: use depends on STATE_control, SET_tilt, SET_Vtip of FltState
hover and helicopter mode ($V \leq V_{\rm conv-hover}$): use tilt=90, Vtip_hover, kgear_hover, kcont_hover
cruise mode ($V \geq V_{\rm conv-cruise}$): use tilt=0, Vtip_cruise, kgear_cruise, kcont_cruise
conversion mode: tilt linear with V, use Vtip_hover, kgear_conv, kcont_conv
nacelle tilt angle: 0 for cruise, 90 deg for helicopter mode flight

---

		+	Never-exceed speed	
SET_VNE	c*32	+	model	'none'
iSET_VNE	int		limits defined (0 for none)	
iSET_VNE_table	int		table (3 for 3D)	
iSET_VNE_stall	int		stall	
iSET_VNE_comp	int		compressibility	
iSET_VNE_Mat	int		Mach number	
		+	table	
KIND_VNE_table	int	+	velocity (0 TAS, 1 CAS, 2 IAS)	0
nwt_VNE	int	+	number of weights (maximum nvnemax)	
nalt_VNE	int	+	number of altitudes (maximum nvnemax)	
ntemp_VNE	int	+	number of temperatures (maximum nvnemax)	
rwt_VNE(nvnemax)	real	+	weight ratio $r_W = W_G/W_D$ (fraction DGW)	
alt_VNE(nvnemax,nvnemax)	real	+	density altitude h_d(nalt,nwt)	
temp_VNE(nvnemax)	real	+	temperature τ (deg C)	
VNE(nvnemax,nvnemax)	real	+	never-exceed speed V_{NEt}(nalt,nwt) (knots)	
VNE3(nvnemax,nvnemax,nvnemax)	real	+	never-exceed speed V_{NEt}(nalt,nwt,ntemp) (knots)	
KIND_VNE_stall(nrotormax)	int	+	stall model, each rotor (0 for no limit, 1 steady, 2 transient, 3 equation)	3
C_VNE(5)	real	+	compressibility limit constants C_n	
Mat_VNE(nrotormax)	real	+	advancing tip Mach number M_{at}, each rotor (0. for no limit)	1.
		+	limits (0. not used)	
VNEmaxTAS	real	+	TAS maximum (knots)	0.
VNEmaxIAS	real	+	IAS maximum (knots)	0.
VNEminTAS	real	+	TAS minimum (knots)	0.
VNEminIAS	real	+	IAS minimum (knots)	0.

---

never-exceed speed: calculate $V_{\rm NE}$ in knots TAS; depends on density altitude h_d, gross weight W_G (in terms of weight ratio $r_W = W_G/W_D$, fraction DGW), and temperature τ

SET_VNE = 'none', or one to four of ('table' or 'table3', 'stall', 'comp', 'Mat')

table limit (2D): $V_{{\rm NE}t}(h_d)$ for set of weights r_W (alt_VNE(nalt,nwt))

table limit (3D): $V_{{\rm NE}t}(h_d, r_W, \tau)$ (alt_VNE not depend on weight)

stall limit: $V_{{\rm NE}s}$ from rotor thrust capability (C_T/σ vs μ)

compressibility limit: $V_{{\rm NE}c} = C_1 - C_2 h_d + C_3 \tau - C_4 V_{\rm tip} - C_5 r_W$ (knots IAS; temperature in deg C)

Mach number limit: $V_{{\rm NE}m}$ from advancing tip Mach number M_{at}

		+	Indicated airspeed correction	
nIAS	int	+	number of values (maximum niasmax, 0 no correction)	0
IAS(niasmax)	real	+	indicated airspeed (knots)	
CAS(niasmax)	real	+	calibrated airspeed (knots)	
dIAS(niasmax)	real		CAS-IAS	
SET_Vschedule	int	+	Velocity schedules (1 CAS, 2 TAS, 3 IAS)	1

---

indicated airspeed correction: IAS(1)=CAS(1)=0., both IAS and CAS unique and sequential

velocity schedules: all described as function CAS or TAS or IAS

conversion, controls and motion, rotor tip speed, landing gear retraction, trim targets, drive system ratings

---

		+	Trim states	
nstate_trim	int	+	number of trim states (maximum ntrimstatemax)	1
IDENT_trim(ntrimstatemax)	c*12	+	label of trim state	
mtrim(ntrimstatemax)	int	+	number of trim variables (maximum mtrimmax)	0
trim_quant(mtrimmax,ntrimstatemax)	c*16	+	trim quantity name	
trim_var(mtrimmax,ntrimstatemax)	c*16	+	trim variable name	
trim_target(mtrimmax,ntrimstatemax)	int	+	target source (1 FltState, 2 component)	1
			Derived trim states	
itrim_quant(mtrimmax,ntrimstatemax)	int		trim quantity name (TRIM_QUANT_xxx)	
itrim_quantn(mtrimmax,ntrimstatemax)	int		trim quantity structure number	
itrim_quantk(mtrimmax,ntrimstatemax)	int		trim quantity kind (0 other, 1 rotor, 2 rotor lift, 3 rotor prop, 4 wing, 5 wing lift)	
itrim_var(mtrimmax,ntrimstatemax)	int		trim variable name (TRIM_VAR_xxx, or control number)	
itrim_varn(mtrimmax,ntrimstatemax)	int		trim variable structure number	

---

trim state: one or more set of quantities and variables for trim iteration
FltState identifies trim state (STATE_trim match IDENT_trim),
trim variable:

description	trim_var	
aircraft control	match IDENT_control	
aircraft orientation	'pitch', 'roll'	body axes relative inertial axes
aircraft velocity	'speed', 'ROC'	horizontal, vertical flight speed
aircraft velocity	'side'	sideslip angle
aircraft angular rate	'pullup', 'turn'	Euler angle rates
propulsion group tip speed	'Vtip n'	
propulsion group engine speed	'Nspec n'	

trim quantity:

description	trim_quant	target
aircraft total force	'force x', 'force y', 'force z'	zero
aircraft total moment	'moment x', 'moment y', 'moment z'	zero
aircraft load factor	'nx', 'ny', 'nz'	FltState%trim_target
propulsion group power	'power n'	FltState%trim_target
power margin	'P margin n'	FltState%trim_target
torque margin	'Q margin n'	FltState%trim_target
engine group power	'power EG n'	FltState%trim_target
power margin	'E margin n'	FltState%trim_target
momentum margin	'FE margin n'	FltState%trim_target
jet group thrust	'jet n'	FltState%trim_target
jet thrust margin	'J margin n'	FltState%trim_target
momentum margin	'FJ margin n'	FltState%trim_target
charge group power	'charge n'	FltState%trim_target
charge power margin	'C margin n'	FltState%trim_target
fuel tank energy flow	'tank n'	FltState%trim_target
battery power margin	'B margin n'	FltState%trim_target
rotor lift	'lift rotor n', 'flift rotor n'	FltState%trim_target, Rotor%Klift
rotor lift	'CLs rotor n', 'vert rotor n'	FltState%trim_target, Rotor%Klift
rotor propulsive force	'prop rotor n', 'fprop rotor n'	FltState%trim_target, Rotor%Kprop
rotor propulsive force	'CXs rotor n', 'X/q rotor n'	FltState%trim_target, Rotor%Kprop
rotor thrust	'CTs rotor n'	FltState%trim_target, Rotor%Klift
rotor thrust margin	'T margin n'	FltState%trim_target
rotor thrust margin	'T margin tran n', 'T margin eqn n'	FltState%trim_target
rotor shaft power	'power rotor n'	FltState%trim_target
rotor flapping	'betac n', 'lngflap n'	FltState%trim_target
rotor flapping	'betas n', 'latflap n'	FltState%trim_target
rotor hub moment	'hub Mx n', 'roll n'	FltState%trim_target
rotor hub moment	'hub My n', 'pitch n'	FltState%trim_target
rotor torque	'hub Mz n', 'torque n'	FltState%trim_target
wing lift	'lift wing n', 'flift wing n'	FltState%trim_target, Wing%Klift
wing lift coefficient	'CL wing n'	FltState%trim_target, Wing%Klift
wing lift margin	'L margin n'	FltState%trim_target
tail lift	'lift tail n'	FltState%trim_target

if trim_target=1, trim quantity target value is FltState%trim_target; otherwise component Klift or Kprop used
if trailing "n" is absent, use first component (n=1)

trim_quant='flift rotor n' or trim_quant='flift wing n': target is fraction total aircraft lift (GW*nAC(3))
trim_quant='fprop rotor n': target is fraction total aircraft drag (qAC*DoQ)
trim_quant='T margin n' uses Rotor%CTs_steady, trim_quant='T margin tran n' uses Rotor%CTs_tran
trim_quant='T margin eqn n' uses equation for rotor thrust capability (Rotor%K0_limit and Rotor%K1_limit)

trim_var='Vtip' or 'Nspec': requires FltAircraft%SET_Vtip='input'

		+	Geometry	
INPUT_geom	int	+	input (1 fixed, SL/BL/WL; 2 scaled, from XoL/YoL/ZoL)	2
		+	scaled geometry	
		+	reference length	
KIND_scale	int	+	kind (1 rotor radius, 2 wing span, 3 fuselage length)	1
kScale	int	+	identification (component number)	1
		+	reference point	
KIND_Ref	int	+	kind (0 input, 1 rotor, 2 wing, 3 fuselage, 4 center of gravity)	0
kRef	int	+	identification (component number)	1
SL_Ref	real	+	stationline	
BL_Ref	real	+	buttline	
WL_Ref	real	+	waterline	
			calculated reference point (input or component)	
SLref	real		stationline	
BLref	real		buttline	
WLref	real		waterline	
loc_cg	Location	+	baseline center of gravity location	

Geometry: Location for each component
fixed geometry input (INPUT_geom = 1): dimensional SL/BL/WL
stationline + aft, buttline + right, waterline + up; arbitary origin; units = ft or m

scaled geometry input (INPUT_geom = 2): divided by reference length (KIND_scale, kScale)
XoL + aft, YoL + right, ZoL + up; from reference point
option to fix some geometry (FIX_geom in Location override INPUT_geom)
option to specify reference length (KIND_scale in Location override this global KIND_scale)
reference point: KIND_Ref, kRef; input dimensional XX_Ref, or position of identified component
component reference must be fixed
certain Locations can be calculated from other parameters (configuration specific)
center of gravity: baseline is for nacelle angle = 90
flight state has calculated or input actual cg location

		+	Takeoff flight condition	
SET_atmos	c*12	+	atmosphere specification	'std'
temp	real	+	temperature τ	
dtemp	real	+	temperature increment ΔT	0.
density	real	+	density ρ	
csound	real	+	speed of sound c_s	
viscosity	real	+	viscosity μ	
altitude	real	+	altitude	
			Derived takeoff flight condition	
iSET_atmos	int		atmosphere (SET_atmos_xxx)	
density_to	real		density ρ	
sigma_to	real		density ratio ρ/ρ_0	
theta_to	real		temperature ratio T/T_0	
delta_to	real		pressure ratio p/p_0	

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takeoff condition (density) used for C_T/σ in rotor sizing
SET_atmos, atmosphere specification:
'std' = standard day at specified altitude (use altitude)
'dtemp' = standard day at specified altitude, plus temperature increment (use altitude, dtemp)
'temp' = standard day at specified altitude, and specified temperature (use altitude, temp)
'dens' = input density and temperature (use density, temp)
'input' = input density, speed of sound, and viscosity (use density, csound, viscosity)
'notair' = input, not air on earth (use density, csound, viscosity)
see FltState%SET_atmos for other options (polar, tropical, and hot days)

		Size
diskload	real	aircraft disk loading (lb/ft^2 or N/m^2)
Aref	real	reference rotor area
wingload	real	aircraft wing loading (lb/ft^2 or N/m^2)
Sref	real	reference wing area
Pav	real	total takeoff power available
powerload	real	aircraft power loading
Tav	real	total takeoff thrust available
thrustload	real	aircraft weight-to-thrust

aircraft disk loading = $W_D/A_{\rm ref}$, $A_{\rm ref} = \sum f_A A$; rotor disk loading = $f_W W_D/A$
aircraft wing loading = $W_D/S_{\rm ref}$, $S_{\rm ref} = \sum S$; individual wing loading = $f_W W_D/S$
aircraft power loading = W_D/P_{av}, $P_{av} = \sum N_{\rm eng} P_{\rm eng}$ (each engine group at takeoff rating)
aircraft thrust-to-weight = W_D/T_{av}, $T_{av} = \sum N_{\rm jet} T_{\rm jet}$ (each jet group at takeoff rating)

		Configuration
nWingExt	int	wing extensions (0 for none)
nWingExtKit	int	wing extension kits (0 for none)
nWingKit	int	wing kits (0 for none)
nWotherkit	int	other kit (0 for none)
SET_fold	int	folding (0 none, 1 fold weights, 2 with kit) (from Systems)
		Neutral point
SLna	real	stationline SL_{na}
		Operating size (hover; controls = 0 except tilt = 90)
length_op	real	length
width_op	real	width
area_op	real	area
		Fuel tank system
burnweight	int	first fuel tank that burns weight (0 none)
eref	real	reference specific energy (MJ/kg)
		Cost
CAC	real	aircraft C_{AC}
CAC_nokit	real	aircraft C_{AC}, folding kit not installed

Cmaint	real	maintenance $C_{\rm maint}$
Cmaint_nokit	real	maintenance $C_{\rm maint}$, folding kit not installed
factor_inf	real	inflation factor F_i (year_inf relative 1994, including factor inflation)
factor_inf2011	real	inflation factor F_i (2011 relative 1994, CPI)
factor_inf2018	real	inflation factor F_i (2018 relative 1994)
Ccomp	real	composite cost increment $C_{\rm comp}$
CMEP	real	mission equipment package cost $C_{\rm MEP}$
CFCE	real	flight control electronics cost $C_{\rm FCE}$
Cbatt	real	battery cost $C_{\rm batt}$
Wcomp	real	composite weight increment $W_{\rm comp}$
WMEP	real	mission equipment package weight $W_{\rm MEP}$
WFCE	real	flight control electronics weight $W_{\rm FCE}$
Wbatt	real	battery weight $W_{\rm batt}$
Ebatt	real	battery capacity $E_{\rm batt}$
Kconfig	real	configuration factor, $K_{ET}K_{EN}K_{LG}K_R$
rAF	real	airframe C_{AF}/W_{AF} ($/lb or $/kg)
rAC	real	total aircraft C_{AC}/W_{EK} ($/lb or $/kg)
WAFcost	real	airframe weight W_{AF}
WEKcost	real	W_{EK} = weight empty + airframe kits = $W_{AF} + W_{\rm MEP} + W_{\rm FCE} + W_{\rm batt}$
Pcost	real	rated takeoff power P
Clabor	real	labor cost $C_{\rm labor}$
Cparts	real	parts cost $C_{\rm parts}$
Cengine	real	engine overhaul cost $C_{\rm engine}$
Cmajor	real	major periodic maintenance cost $C_{\rm major}$
Cbattmaint	real	battery maintenance cost $C_{\rm batt-maint}$
MMHperFH	real	maintenance man hours per flight hour
CACcomp	real	aircraft C_{AC} from components
rACcomp	real	total aircraft C_{AC}/W_{EK} ($/lb or $/kg)
rAFcomp	real	airframe flyaway C_{FA}/W_{AF} ($/lb or $/kg)
rPQcomp	real	prime equipment c_{pq}/W_{AF} ($/lb or $/kg)
dCMEP	real	mission equipment package cost increment $\Delta C_{\rm MEP}$
dCFCE	real	flight control electronics cost increment $\Delta C_{\rm FCE}$
c_FA	real	aircraft flyaway
c_pq	real	prime equipment (including inflation and technology factor)

c_int_SE	real		integration/assemmbly and systems engineering	
c_profit	real		profit	
c_wing	real		wing	
c_rotor	real		rotor	
c_fuselage	real		fuselage	
c_emp_nac_LG	real		empennage, nacelle, and landing gear	
c_engine	real		engine	
c_prop	real		propeller	
c_xmsn	real		transmission	
c_FC_inst_hyd	real		flight controls, instruments, and hydraulic systems	
c_aux_fuelsys	real		auxiliary power system, fuel system, exhaust, propulsion controls and accessories	
c_elect	real		electrical	
c_avionics	real		avionics	
c_arm_furn_load	real		armament provisions, furnishings, and load and handling	
c_env	real		environmental	
		+	Weight	
DGW	real	+	design gross weight W_D	
Wfuel_DGW	real	+	mission fuel W_{fuel} corresponding to DGW	
Wpay_DGW	real	+	payload W_{pay} corresponding to DGW	
WE	real	+	weight empty W_E	
dWE	real	+	weight increment	
fWE	real	+	weight factor	
		+	structural design gross weight	
SDGW	real	+	structural design gross weight W_{SD}	
dSDGW	real	+	weight increment	0.
fSDGW	real	+	weight factor	1.
fFuelSDGW	real	+	fraction main fuel tanks filled at SDGW	1.
		+	maximum takeoff weight	
WMTO	real	+	maximum takeoff weight W_{MTO}	
dWMTO	real	+	weight increment	0.
fWMTO	real	+	weight factor	1.
nz_ult	real	+	design ultimate flight load factor $n_{z\text{ult}}$ at SDGW	6.0

input or calculated: design gross weight W_D (FIX_DGW), structural design gross weight W_{SD} (SET_SDGW), maximum takeoff weight W_{MTO} (SET_WMTO), weight empty W_E (FIX_WE)
    if calculated, then input parameter is initial value

DGW, design gross weight: used for rotor disk loading and blade loading, wing loading, power loading, thrust loading
    to obtain aircraft moments of inertia from radii of gyration
    for tolerance and perturbation scales of the solution procedures
    optionally to define structural design gross weight and maximum takeoff weight
    optionally to specify the gross weight for missions and flight conditions
Wfuel_DGW and Wpay_DGW usually calculated (identified as input so inherited by next case)

FIX_WE: fixed or scaled weight empty obtained by adjusting contingency weight
    scaled with design gross weight: W_E=dWE+fWE*W_D

SET_SDGW, structural design gross weight:
    'input' = input
    'f(DGW)' = based on DGW; W_{SD}=dSDGW+fSDGW*W_D
    'f(WMTO)' = based on WMTO; W_{SD}=dSDGW+fSDGW*W_{MTO}
    'maxfuel' = based on fuel state; W_{SD}=dSDGW+fSDGW*W_G, $W_G = W_D$–Wfuel_DGW+fFuelSDGW*$W_{\text{fuel}-\text{cap}}$
    'perf' = calculated from maximum gross weight at SDGW sizing conditions (DESIGN_sdgw)
SET_WMTO, maximum takeoff weight:
    'input' = input
    'f(DGW)' = based on DGW; W_{MTO}=dWMTO+fWMTO*W_D
    'f(SDGW)' = based on SDGW; W_{MTO}=dWMTO+fWMTO*W_{SD}
    'maxfuel' = based on maximum fuel; W_{MTO}=dWMTO+fWMTO*W_G, $W_G = W_D$–Wfuel_DGW+$W_{\text{fuel}-\text{cap}}$
    'perf' = calculated from maximum gross weight at WMTO sizing conditions (DESIGN_wmto)
SDGW used for weights (fuselage, rotor, wing)
WMTO used for cost, drag (scaled aircraft and hub drag), and weights (system, fuselage, landing gear, engine group)
nz_ult, design ultimate flight load factor at SDGW: used for weights (fuselage, rotor, wing)

		+	Weight	
Weight	Weight		aircraft weight statement (operating weight, without payload and usable fuel)	
WO	real		operating weight W_O	
growth_factor	real		growth factor = $W_D/(W_D - W_{\rm scaled} - W_{\rm fuel})$	
		+	moments of inertia (based on design gross weight, scaled with reference length)	
kx	real	+	roll radius of gyration k_x/L	
ky	real	+	pitch radius of gyration k_y/L	
kz	real	+	yaw radius of gyration k_z/L	
			Derived moments of inertia (corresponding to aircraft weight statement)	
Ixx	real		I_{xx}	
Iyy	real		I_{yy}	
Izz	real		I_{zz}	
Ixy	real		I_{xy}	
Iyz	real		I_{yz}	
Ixz	real		I_{xz}	

---

weight empty = structure + propulsion + systems and equipment + vibration + contingency
operating weight = weight empty + fixed useful load
weight statement defines fixed useful load and operating weight for design configuration
    so for flight state, additional fixed useful load = auxiliary fuel tank and kits and increments
    flight state can also increment crew weight or equipment weight
flight state: gross weight, useful load (payload, usable fuel, fixed useful load), operating weight
    gross weight = weight empty + useful load = operating weight + payload + usable fuel
    useful load = fixed useful load + payload + usable fuel

		+	Drag	
FIX_drag	int	+	total aircraft D/q (0 calculated; 1 fixed, input D/q; 2 scaled, input C_D; 3 scaled, from k)	0
DoQ	real	+	area D/q	0.
CD	real	+	coefficient C_D (based on rotor area, $D/q = A_{\rm ref} C_D$)	0.008
kDrag	real	+	$k = (D/q)/(W_{MTO}/1000)^{2/3}$ (Units_Dscale)	2.5
FIX_DL	int	+	total aircraft download (0 calculated; 1 fixed, input D/q_V; 2 scaled, from k_{DL})	0
DoQV	real	+	area $(D/q)_V$	0.
kDL	real	+	$k_{DL} = (D/q)_V/A_{\rm ref}$	0.05

---

fixed drag or download: obtained by adjusting contingency D/q or $(D/q)_V$
FIX_drag: minimum drag, excludes drag due to lift and angle of attack
use only one of input DoQ, CD, kDrag (others calculated)
A_{ref} = reference rotor area; units of kDrag are ft^2/klb$^{2/3}$ or m^2/Mg$^{2/3}$
CD = 0.02 for old helicopter, 0.008 for current low drag helicopters
kDrag = 9 for old helicopter, 2.5 for current low drag helicopters,
1.6 for current tiltrotors, 1.4 for turboprop aircraft (English units)
FIX_DL, download: A_{ref} = reference rotor area, kDL $\sim DL/T$
use only one of DoQV, kDL (other calculated)

		+	Aerodynamics	
KIND_alpha	int	+	angle of attack and sideslip angle representation (1 conventional, 2 reversed for sideward flight)	2

---

angle of attack and sideslip angle: reversed definition best for sideward flight

---

		Derived aircraft drag	
DoQC_comp	real	sum component cruise drag, area $(D/q)_{\text{comp}}$ (without contingency)	
DoQH_comp	real	sum component helicopter drag, area $(D/q)_{\text{comp}}$ (without contingency)	
DoQV_comp	real	sum component vertical drag, area $(D/q)_{\text{comp}}$ (without contingency)	
DoQC_AC	real	total cruise drag, area $(D/q)_{AC}$	
DoQH_AC	real	total helicopter drag, area $(D/q)_{AC}$	
DoQV_AC	real	total vertical drag, area $(D/q)_{AC}$	
CDC_AC	real	total cruise $(D/q)_{AC}/A_{\text{ref}}$	
CDH_AC	real	total helicopter $(D/q)_{AC}/A_{\text{ref}}$	
kDragC_AC	real	total cruise $(D/q)/(W_{MTO}/1000)^{2/3}$	
kDragH_AC	real	total helicopter $(D/q)/(W_{MTO}/1000)^{2/3}$	
kDL_AC	real	total vertical $(D/q)_V/A_{\text{ref}}$	
DoQwet_AC	real	total cruise wetted drag, area $(D/q)_{\text{wet}}$	
Swet_AC	real	total wetted area S_{wet}	
CD_AC	real	total cruise $(D/q)_{\text{wet}}/S_{\text{wet}}$	

		+	Number of Components	
nRotor	int	+	rotors (maximum nrotormax)	2
nWing	int	+	wings (maximum nwingmax)	0
nTail	int	+	tails (maximum ntailmax)	1
nTank	int	+	fuel tank systems (maximum ntankmax)	1
nPropulsion	int	+	propulsion groups (maximum npropmax)	1
nEngineGroup	int	+	engine groups (maximum nengmax)	1
nJetGroup	int	+	jet groups (maximum njetmax)	0
nChargeGroup	int	+	charge groups (maximum nchrgmax)	0
nEngineModel	int	+	engine models (maximum nengmax)	1
nEngineParamN	int	+	engine model parameters (maximum nengpmax)	0
nEngineTable	int	+	engine tables (maximum nengmax)	0
nRecipModel	int	+	reciprocating engine models (maximum nengmax)	0
nCompressorModel	int	+	compressor models (maximum nengmax)	0
nMotorModel	int	+	motor models (maximum nengmax)	0
nJetModel	int	+	jet models (maximum njetmax)	0
nFuelCellModel	int	+	fuel cell models (maximum nchrgmax)	0
nSolarCellModel	int	+	solar cell models (maximum nchrgmax)	0
nBatteryModel	int	+	battery models (maximum ntankmax)	0

---

propulsion group is set of components and engine groups, connected by drive system
engine model or engine table or reciprocating engine or motor model describes particular engine,
used in one or more engine groups
jet model describes particular jet, used in one or more jet groups
fuel cell model or solar cell model describes particular charger, used in one or more charge groups
battery model describes particular battery, used in one or more fuel tanks

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		Aircraft Input for case
inAircraft	int	Aircraft
inSystems	int	Systems
inFuselage	int	Fuselage
inLandingGear	int	LandingGear

inRotor(nrotormax)	int	Rotor
inWing(nwingmax)	int	Wing
inTail(ntailmax)	int	Tail
inFuelTank(ntankmax)	int	FuelTank
inPropulsion(npropmax)	int	Propulsion
inEngineGroup(nengmax)	int	EngineGroup
inJetGroup(njetmax)	int	JetGroup
inChargeGroup(nchrgmax)	int	ChargeGroup
inEngineModel(nengmax)	int	EngineModel
inEngineParamN(nengpmax)	int	EngineParamN
inEngineTable(nengmax)	int	EngineTable
inRecipModel(nengmax)	int	RecipModel
inCompressorModel(nengmax)	int	CompressorModel
inMotorModel(nengmax)	int	MotorModel
inJetModel(njetmax)	int	JetModel
inFuelCellModel(nchrgmax)	int	FuelCellModel
inSolarCellModel(nchrgmax)	int	SolarCellModel
inBatteryModel(ntankmax)	int	BatteryModel
inCost	int	Cost
inEmissions	int	Emissions
		Design specification (from Size)
iSIZE_perf(npropmax)	int	performance (SIZE_perf_engine, rotor, none)
iSIZE_engine(nengmax)	int	performance (SIZE_engine_engn, none)
iSIZE_jet(njetmax)	int	performance (SIZE_jet_jet, none)
iSIZE_charge(nchrgmax)	int	performance (SIZE_charge_chrg, none)
iSIZE_rotor(nrotormax)	int	rotor sized (SIZE_rotor_radius, thrust, none)
iSET_rotor_radius(nrotormax)		
	int	rotor radius (SET_rotor_radius, DL, ratio, scale, not_radius)
FIX_rotor_CWs(nrotormax)	int	rotor C_W/σ (1 fixed, 0 not)
FIX_rotor_Vtip(nrotormax)	int	rotor $V_{\rm tip}$ (1 fixed, 0 not)
FIX_rotor_sigma(nrotormax)	int	rotor σ (1 fixed, 0 not)
iSET_wing_area(nwingmax)	int	wing area (SET_wing_area, WL, not_area)
iSET_wing_span(nwingmax)	int	wing span (SET_wing_span, ratio, radius, width, hub, panel, not_span)
FIX_wing_chord(nwingmax)	int	wing chord (1 fixed, 0 not)

FIX_wing_AR(nwingmax)	int	wing aspect ratio (1 fixed, 0 not)
FIX_DGW	int	design gross weight (0 calculated, 1 fixed)
FIX_WE	int	weight empty (0 calculated, 1 fixed, 2 scaled)
iSET_tank(ntankmax)	int	fuel tank (SET_tank_input, miss, fmiss, used)
iSET_tank_power(ntankmax)	int	fuel tank (SET_tank_nopower, power)
iSET_SDGW	int	SDGW (SET_SDGW_input, fDGW, fWMTO, maxfuel, perf)
iSET_WMTO	int	WMTO (SET_WMTO_input, fDGW, fSDGW, maxfuel, perf)
iSET_limit_ds(npropmax)	int	drive system torque limit (SET_limit_input, ratio, Pav, Preq)
kind_iter_size	int	kind iteration, performance (0 none, 1 size engine or radius or jet group or charge group)
kind_iter_param	int	kind iteration, parameters (0 none, 1 calculate parameters)
nSIZE_perf(npropmax)	int	conditions and missions for size engine or rotor
nSIZE_engine(nengmax)	int	conditions and missions for size engine group
nSIZE_jet(njetmax)	int	conditions and missions for size jet group
nSIZE_charge(nchrgmax)	int	conditions and missions for size charge group
nDESIGN_GW	int	design conditions and missions for DGW
nDESIGN_xmsn(npropmax)	int	design conditions and missions for transmission
nDESIGN_wmto	int	design conditions for WMTO
nDESIGN_tank	int	design missions for fuel tank
nDESIGN_thrust	int	design conditions and missions for antitorque or aux thrust rotor
		Design data (from sizing)
DGW_source	int	design gross weight source (1 condition, 2 mission)
DGW_kState	int	design gross weight source number
DGW_kSeg	int	design gross weight segment number
nDesignState	int	number design of conditions and missions (maximum ndesignmax)
XAircraft(ndesignmax)	XAircraft	design data

Chapter 35

Structure: XAircraft

Variable	Type	Description	Default
		Design Data	
source	int	source (1 condition, 2 mission)	
kState	int	source number	
kSeg	int	segment number	
title	c*100	title	
kind	c*12	kind (condition or mission)	
number	c*12	number (condition or mission/segment)	
label	c*12	label	
setgw	c*12	Set Gross Weight	
setul	c*12	Set Useful Load	
design	c*12	design	
Nauxtank(nauxtankmax,ntankmax)			
	int	number of auxiliary fuel tanks N_{auxtank} (each aux tank size)	
Ncrew	int	number of crew	
Npass	int	number of passengers	
Ncrew_seat	int	number of crew seats	
Npass_seat	int	number of passenger seats	
kits	c*12	kits	
		Weights (from FltAircraft)	
GW	real	gross weight W_G; at segment start	
Wpayload	real	payload weight W_{pay}	
Wpay_pass	real	passengers W_{pass}	
Wpay_cargo	real	cargo W_{cargo}	
Wpay_extload	real	external load $W_{\text{ext-load}}$	
Wpay_ammo	real	ammunition W_{ammo}	
Wpay_weapons	real	weapons W_{weapons}	
Wpay_other	real	other W_{other}	

Wfuel_total	real	usable fuel weight W_{fuel}; at segment start
Wfuel(ntankmax)	real	usable fuel weight
Wfuel_std(ntankmax)	real	standard tanks
Wfuel_aux(ntankmax)	real	auxiliary tanks
WO	real	operating weight W_O
WE	real	weight empty W_E (from Aircraft)
WFixUL	real	fixed useful load W_{FUL}
Wcrew	real	crew
W_fixUL_fluid	real	fluids (from Aircraft%Weight)
Wauxtank	real	auxiliary fuel tanks
W_fixUL_other	real	other fixed useful load
Woful(10)	real	catagories
Wequip	real	equipment increment
Wfoldkit	real	folding kit
Wextkit	real	wing extension kit
Wwingkit	real	wing kit
Wotherkit	real	other kit
WUL	real	useful load W_{UL}
WML	real	military load
		Energy (from FltAircraft)
Efuel_total	real	usable fuel energy E_{fuel}; at segment start
Efuel(ntankmax)	real	usable fuel energy
Efuel_std(ntankmax)	real	standard tanks
Efuel_aux(ntankmax)	real	auxiliary tanks

Chapter 36

Structure: Systems

Variable	Type		Description	Default
		+	Systems	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Weight	
Weight	Weight		weight statement (systems)	
SET_Wpayload	int	+	payload (1 no details; 2 all terms)	1
Upass	real	+	weight per passenger	
		+	fixed useful load	
SET_Wcrew	int	+	crew weight (1 no details; 2 all terms)	1
Wcrew	real	+	weight or adjustment	
Ucrew	real	+	weight per crew	
Ncrew	int	+	number of crew	
Wtrap	real	+	trapped fluids and engine oil weight	0.
		+	other fixed useful load	
nWoful	int	+	number of categories (0 for one value without name; maximum 10)	0
Woful_name(10)	c*24	+	category name	' '
Woful(10)	real	+	baseline weight	0.
Wotherkit	real	+	other kit	0.

SET_Wpayload: payload specified by flight condition or mission
SET_Wcrew: no details (only Wcrew) or all terms (Ucrew*Ncrew+Wcrew)

other fixed useful load: can include baggage, gun installations, weapons provisions, aircraft survivability equipment, survival kits, life rafts, oxygen

SET_fold	int	+	folding (0 none, 1 fold weights, 2 with kit)	0
		+	folding weight in kit $f_{\rm foldkit}$ (fraction wing/rotor/tail/body fold weight)	
fWfoldkitW(nwingmax)	real	+	wing	0.5
fWfoldkitR(nrotormax)	real	+	rotor	0.5
fWfoldkitT(ntailmax)	real	+	tail	0.5
fWfoldkitFw	real	+	body (wing and rotor fold)	0.5
fWfoldkitFt	real	+	body (tail fold)	0.5
SET_Wvib	int	+	vibration treatment weight (1 fraction weight empty, 2 input)	1
Wvib	real	+	weight $W_{\rm vib}$	
fWvib	real	+	fraction weight empty $f_{\rm vib}$	
SET_Wcont	int	+	contingency weight (1 fraction weight empty, 2 input)	1
Wcont	real	+	weight $W_{\rm cont}$	
fWcont	real	+	fraction weight empty $f_{\rm cont}$	

W_E = (structure + propulsion group + systems and equipment) + $W_{\rm vib}$ + $W_{\rm cont}$
SET_Wvib: $W_{\rm vib}$ input or $W_{\rm vib} = f_{\rm vib} W_E$
SET_Wcont: $W_{\rm cont}$ input or $W_{\rm cont} = f_{\rm cont} W_E$; or adjust $W_{\rm cont}$ for input or scaled W_E (FIX_WE=1 or 2)

SET_fold, folding:
set component dWxxfold=0 and fWxxfold=0 for no rotor/wing/tail/body fold weight
fraction fWfoldkit of fold weight in fixed useful load as kit, remainder kept in component weight
kit weight removable, absent for specified flight conditions and missions

		+	systems and equipment	
Wauxpower	real	+	auxiliary power group (APU)	0.
Winstrument	real	+	instruments group	0.
Wpneumatic	real	+	pneumatic group	0.
Wenviron	real	+	environmental control group	0.
SET_Welectrical	int	+	electrical group (1 no details; 2 all terms)	1
Welectrical	real	+	aircraft	0.
Welect_supply	real	+	power supply	0.
Welect_conv	real	+	power conversion	0.
Welect_distrib	real	+	power distribution and controls	0.

Welect_lights	real	+	lights and signal devices	0.
Welect_support	real	+	equipment supports	0.
SET_WMEQ	int	+	avionics group (1 no details; 2 all terms)	1
WMEQ	real	+	avionics	0.
Wavionics_com	real	+	communications	0.
Wavionics_nav	real	+	navigation	0.
Wavionics_ident	real	+	identification	0.
Wavionics_disp	real	+	control and display	0.
Wavionics_survive	real	+	aircraft survivability	0.
Wavionics_mission	real	+	mission system equipment	0.
		+	armament group	
SET_Warmor	int	+	armor (1 no details; 2 all terms)	1
Warmor	real	+	armor	0.
Uarmor_floor	real	+	cabin floor armor weight per area	
Uarmor_wall	real	+	cabin wall armor weight per area	
Uarmor_crew	real	+	armor weight per crew	
SET_Warmprov	int	+	armament provisions (1 no details; 2 all terms)	1
Warmprov	real	+	armament provisions	0.
Warmprov_gun	real	+	gun provisions	0.
Warmprov_turret	real	+	turret systems	0.
Warmprov_expend	real	+	expendable weapons provisions	0.
Warm_elect	real	+	armament electronics (avionics group)	0.
SET_Wfurnish	int	+	furnishings and equipment group (1 no details; 2 all terms)	1
Wfurnish	real	+	furnishings and equipment	0.
		+	accommodations for personnel	
Useat_crew	real	+	each crew seat	
Useat_pass	real	+	each passenger seat	
Uaccom_crew	real	+	miscellaneous accommodation per crew seat	
Uaccom_pass	real	+	miscellaneous accommodation per passenger seat	
Uox_crew	real	+	oxygen system per crew seat	
Uox_pass	real	+	oxygen system per passenger seat	
Wfurnish_misc	real	+	miscellaneous equipment	0.

		+	furnishings	
Wfurnish_trim	real	+	trim	0.
Uinsulation	real	+	acoustic and thermal insulation weight per cabin area	
		+	emergency equipment	
Wemerg_fire	real	+	fire detection and extinguishing	0.
Wemerg_other	real	+	other emergency equipment	0.
SET_Wload	int	+	load and handling group (1 no details; 2 all terms)	1
Wload	real	+	load and handling	0.
Whandling_aircraft	real	+	aircraft handling	0.
		+	load handling	
Uhandling_cargo	real	+	cargo handling weight per cabin floor area	
Wload_hoist	real	+	hoist	0.
Wload_extprov	real	+	external load provisions	0.
		+	systems and equipment	
Ncrew_seat	int	+	number of crew seats	0
Npass_seat	int	+	number of passenger seats	0
Ucrew_seat_inc	real	+	equipment weight increment per crew seat (0. for default)	0.
Upass_seat_inc	real	+	equipment weight increment per passenger seat (0. for default)	0.

SET_Welectrical=1: only Welectrical+WDIelect
SET_WMEQ=1: only WMEQ; equipment weights include installation
SET_Warmor=1: only Warmor
SET_Warmprov=1: only Warmprov
SET_Wfurnish=1: only Wfurnish
miscellaneous accommodation includes galleys and toilets
miscellaneous equipment includes cockpit displays
trim includes floor covering, partitions, crash padding, acoustic and thermal insulation
excluding vibration absorbers
other emergency equipment includes first aid, survival kit, life raft
SET_Wload=1: only Wload

equipment weight increment is for flight condition and mission; default (if SET_furnish=2 and SET_armor=2):
Ucrew_seat_inc=Useat_crew+Uaccom_crew+Uox_crew+Uarmor_crew
Upass_seat_inc=Useat_pass+Uaccom_pass+Uox_pass

			Derived weights	
			fixed useful load, fold kit	
W_fixUL_foldkit_fus	real		fuselage	
W_fixUL_foldkit_rotor	real		rotors	
W_fixUL_foldkit_wing	real		wings	
W_fixUL_foldkit_tail	real		tails	
			armament group	
Warmor_floor	real		cabin floor armor weight	
Warmor_wall	real		cabin wall armor weight	
Warmor_crew	real		crew armor weight	
			furnishings and equipment group	
Wseat	real		seats	
Waccom	real		miscellaneous accommodation	
Wox	real		oxygen system	
Winsulation	real		acoustic and thermal insulation weight	
Whandling_cargo	real		cargo handling weight	
Ucrewseatinc	real		equipment weight increment per crew seat	
Upassseatinc	real		equipment weight increment per passenger seat	
Wtip(nrotormax)	real		weight on wing tip	
		+	Weight	
		+	systems and equipment	
		+	flight control group and hydraulic group	
MODEL_fc	int	+	model (0 input, 1 NDARC, 2 custom)	1
MODEL_RWfc	int	+	rotary wing flight controls (0 not present, 1 global, 2 for each rotor)	1
refRotor	int	+	reference rotor number for global	1
MODEL_FWfc	int	+	fixed wing flight controls (0 for not present)	1
MODEL_CVfc	int	+	conversion controls (0 for not present)	1
		+	flight control weight increment	
dWRWfc_b	real	+	rotary wing, boosted	0.
dWRWfc_mb	real	+	rotary wing, control boost mechanisms	0.
dWRWfc_nb	real	+	rotary wing, non-boosted	0.
dWFWfc_mb	real	+	fixed wing, control boost mechanisms	0.
dWFWfc_nb	real	+	fixed wing, non-boosted	0.
dWCVfc_mb	real	+	conversion, boosted	0.

dWCVfc_nb	real	+	conversion, control boost mechanisms	0.
		+	fixed flight controls	
Wfc_cc	real	+	cockpit controls	0.
Wfc_afcs	real	+	automatic flight control system	0.
		+	hydraulic weight increment	
dWRWhyd	real	+	rotary wing	0.
dWFWhyd	real	+	fixed wing	0.
dWCVhyd	real	+	conversion	0.
WEQhyd	real	+	equipment hydraulics	0.
WFltCont	WFltCont		NDARC model	
		+	anti-icing group	
MODEL_DI	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWDIelect	real	+	electrical system	0.
dWDIsys	real	+	anti-ice system	0.
WDeIce	WDeIce		NDARC model	

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

MODEL_RWfc: global option is based on just main rotors
"for each rotor" option sums separate contributions from all rotors

tiltrotor wing weight model requires weight on wing tip: distributed to designated rotor;
sum rotary wing and conversion flight controls, hydraulic group, trapped fluids

---

		+	Technology Factors	
		+	rotary wing flight control weight	
TECH_RWfc_b	real	+	boosted χ_{RWb}	1.0
TECH_RWfc_mb	real	+	control boost mechanisms χ_{RWmb}	1.0
TECH_RWfc_nb	real	+	non-boosted χ_{RWnb}	1.0

		+	fixed wing flight control weight	
TECH_FWfc_mb	real	+	control boost mechanisms χ_{FWmb}	1.0
TECH_FWfc_nb	real	+	non-boosted χ_{FWnb}	1.0
		+	conversion flight control weight	
TECH_CVfc_mb	real	+	control boost mechanisms χ_{CVmb}	1.0
TECH_CVfc_nb	real	+	non-boosted χ_{CVnb}	1.0
		+	flight control hydraulics	
TECH_RWhyd	real	+	rotary wing $\chi_{RW\text{hyd}}$	1.0
TECH_FWhyd	real	+	fixed wing $\chi_{FW\text{hyd}}$	1.0
TECH_CVhyd	real	+	conversion $\chi_{CV\text{hyd}}$	1.0
		+	anti-icing	
TECH_DIelect	real	+	electrical system $\chi_{DI\text{elect}}$	1.0
TECH_DIsys	real	+	anti-ice system $\chi_{DI\text{sys}}$	1.0

Chapter 37

Structure: WFltCont

Variable	Type		Description	Default
		+	Flight Control Group, NDARC Weight Model	
		+	rotary wing flight controls	
MODEL_WRWfc	int	+	model (1 fraction, 2 parametric, 3 Boeing, 4 GARTEUR, 5 Tishchenko, 6 generic)	1
fRWfc_nb	real	+	AFDD: non-boosted control weight f_{RWnb} (fraction boost mechanisms weight)	0.6
xRWfc_red	real	+	AFDD: hydraulic system redundancy/complexity factor $f_{RW\text{red}}$	3.0
KIND_WRWfc	int	+	AFDD: survivability (1 baseline, 2 UTTAS/AAH level of survivability)	2
fRWfc_b	real	+	Boeing, GARTEUR, Tishchenko, or generic: boosted weight f_{RWb} (fraction boosted + boost mech, or total)	0.2
fRWfc_mb	real	+	GARTEUR, Tishchenko, or generic: boost mechanisms weight f_{RWmb} (fraction total weight)	0.2
KRW	real	+	generic: factor K_{RW}	0.
XRWN	real	+	exponent X_{RWN}	0.
XRWR	real	+	exponent X_{RWR}	0.
XRWc	real	+	exponent X_{RWc}	0.
XRWW	real	+	exponent X_{RWW}	0.
XRWb	real	+	exponent X_{RWb}	0.
		+	fixed wing flight controls	
MODEL_WFWfc	int	+	model (1 full controls, 2 only on hor tail, 3 GARTEUR, Raymer (4 transport, 5 general aviation), 6 generic)	1
fFWfc_nb	real	+	non-boosted weight f_{FWnb} (fraction total fixed wing flight control weight)	0.10
nfunction	int	+	Raymer: number of control functions	6
fmech	real	+	Raymer: number of mechanical functions (fraction total)	0.2
KFW	real	+	generic, factor K_{FW}	0.
XFW	real	+	exponent X_{FW}	0.
		+	conversion controls	
fCVfc_mb	real	+	boost mechanisms weight f_{CVmb} (fraction maximum takeoff weight)	0.02
fCVfc_nb	real	+	non-boosted weight f_{CVnb} (fraction boost mechanisms weight)	0.10
		+	cockpit controls	
MODEL_cc	int	+	model (1 fixed Wfc_cc, 2 scaled with DGW)	1
Kcc	real	+	factor K_{cc}	1.7
Xcc	real	+	exponent X_{cc}	0.41

		+	Hydraulic Group, NDARC Model	
		+	flight control hydraulics	
fRWhyd	real	+	rotary wing $f_{RW\text{hyd}}$ (fraction rotary wing boost mechanisms + hydraulic weight)	0.40
fFWhyd	real	+	fixed wing $f_{FW\text{hyd}}$ (fraction fixed wing boost mechanisms weight)	0.10
fCVhyd	real	+	conversion $f_{CV\text{hyd}}$ (fraction conversion boost mechanisms weight)	0.10

---

flight controls = non-boosted (do not see aero surface or rotor loads) + boost mechanisms (actuators) + boosted

MODEL_WRWfc = fraction: parametric except for non-boosted controls (from fRWfc_nb)

typically fRWfc_nb = 0.6 (data range 0.3 to 1.8), fRWhyd = 0.4
xRWfc_red = 1.0 to 3.0

		+	Custom Weight Model	
WtParam_fc(8)	real	+	parameters	0.
			Weight Model Input	
			Rotary wing	
WMTO_rw	real		maximum takeoff weight	
Wbld_rw	real		blade weight	
Nrotor_rw	int		number of rotors	
NrNb_rw	int		total number of blades, Nrotor*Nblade	
chord_rw	real		blade mean chord	
Vtip_rw	real		hover tip speed	
radius_rw	real		blade radius	
			Fixed wing	
WMTO_fw	real		maximum takeoff weight	
Sht_fw	real		horizontal tail area (fixed wing)	
			Conversion	
WMTO_cv	real		maximum takeoff weight	
			Cockpit controls	
DGW_cc	real		design gross weight	

Chapter 38

Structure: WDeIce

Variable	Type		Description	Default
		+	Anti-Icing Group, NDARC Weight Model	
kDeIce_elec(nrotormax)	real	+	weight factor for electrical system $K_{\rm elec}$ (lb/ft^2 or kg/m^2)	0.25
kDeIce_rotor(nrotormax)	real	+	weight factor for main rotor $K_{\rm rotor}$ (lb/ft^2 or kg/m^2)	0.25
kDeIce_wing(nwingmax)	real	+	weight factor for wing $K_{\rm wing}$ (lb/ft or kg/m)	0.
kDeIce_air(nengmax)	real	+	weight factor for engine air intake $K_{\rm air}$ (lb/lb or kg/kg)	0.006
kDeIce_jet(njetmax)	real	+	weight factor for jet air intake $K_{\rm jet}$ (lb/lb or kg/kg)	0.006
		+	Custom Weight Model	
WtParam_DI(8)	real	+	parameters	0.
			Weight Model Input	
Ablade(nrotormax)	real		blade area	
Lwing(nwingmax)	real		wing length	
Weng(nengmax)	real		engine weight	
Wjet(njetmax)	real		jet weight	

Chapter 39

Structure: Fuselage

Variable	Type		Description	Default
		+	Fuselage	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Geometry	
loc_fuselage	Location	+	fuselage location	
SET_length	int	+	fuselage length (1 input, 2 calculated, 3 from rotor and tail only, 4 from rotor only)	1
Length_fus	real	+	length $\ell_{\rm fus}$	
SET_nose	int	+	nose length (distance forward of hub; 1 input, 2 calculated)	1
Length_nose	real	+	nose length $\ell_{\rm nose}$	
fLength_nose	real	+	nose length (fraction reference length)	
SET_aft	int	+	aft length (distance aft of hub; 1 input, 2 calculated)	1
Length_aft	real	+	aft length $\ell_{\rm aft}$	
fLength_aft	real	+	aft length (fraction reference length)	
fRef_fus	real	+	fuselage SL location relative nose $f_{\rm ref}$ (fraction fuselage length)	
Length_rotors	real		rotor-rotor longitudinal separation	
Length_tail	real		tail length (wing to horizontal tail)	
Width_fus	real	+	fuselage width $w_{\rm fus}$	
SET_Swet	int	+	fuselage wetted area (1 input, 2 input plus boom, 3 from nose length, 4 from fuselage length, 5 from weight)	2
Swet	real	+	wetted area $S_{\rm wet}$	
Sproj	real	+	projected area $S_{\rm proj}$	
fSwet	real	+	factor for wetted area $f_{\rm wet}$ or $k_{\rm wet}$	1.
fSproj	real	+	factor for projected area $f_{\rm proj}$ or $k_{\rm proj}$	1.
Height_fus	real	+	fuselage height $h_{\rm fus}$	
Circum_boom	real	+	tail boom effective circumference $C_{\rm boom}$	
Width_boom	real	+	tail boom effective width $w_{\rm boom}$	
Swet_in	real		input wetted area $S_{\rm wet}$	
Sproj_in	real		input projected area $S_{\rm proj}$	

SET_Scabin	int	+	cabin area (1 input, 2 calculated)	2
Scabin	real	+	total cabin surface area $S_{\rm cabin}$	
Scabin_floor	real	+	cabin floor area $S_{\rm cabin-floor}$	
Scabin_wall	real	+	cabin wall area $S_{\rm cabin-wall}$	
fScabin	real	+	factor for total cabin surface area $f_{\rm cabin}$	0.6
fScabin_floor	real	+	factor for cabin floor area $f_{\rm cabin-floor}$	0.6
fScabin_wall	real	+	factor for cabin wall area $f_{\rm cabin-wall}$	0.6
KIND_scale	int	+	reference length (1 rotor radius, 2 wing span, 3 fuselage length)	1
refRotor	int	+	rotor number (for rotor radius)	1
refWing	int	+	wing number (for wing span)	1

SET_length: input (use Length_fus) or calculated (from nose and aft lengths)
calculated uses rotor, tail, wing locations; or just rotor and tail, or just rotor
which can not then be scaled with fuselage length
SET_nose: input (use Length_nose) or calculated (from fLength_nose); used for Length_fus and Swet
SET_aft: input (use Length_aft) or calculated (from fLength_aft); used for Length_fus
fRef_fus=(SL_fuselage–SL_nose)/Length_fus; used for operating length and sketch
input required if SET_length = input, otherwise calculated

SET_Swet: both wetted area and projected area; input (use Swet, Sproj),
or calculated (from fSwet, fSproj, Width_fus, Height_fus, and fuselage or nose length)
or from weight, units of $k_{\rm wet}$ = fSwet and $k_{\rm proj}$ = fSproj are ft^2/klb$^{2/3}$ or m^2/Mg$^{2/3}$
boom circumference and width used if SET_Swet not input and not from weight (set to zero if no boom)

SET_Scabin: cabin areas used for systems and equipment weights

		+	Geometry (for graphics)	
Height_ramp	real	+	height of cargo ramp	
fLength_cargo	real	+	fraction of fuselage length used for cargo	0.60

		+	Controls	
		+	flow control momentum coefficient C_μ	
INPUT_flow	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_flow(ncontmax,nstatemax)	real	+	control matrix	
nVflow	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
flow(nvelmax)	real	+	values	
Vflow(nvelmax)	real	+	speeds (CAS or TAS)	

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

		+	Aerodynamics	
MODEL_aero	int	+	model (0 none, 1 standard)	1
AFuse	AFuse		standard model	
DoQ_cont	real	+	contingency drag, area $(D/q)_{\rm cont}$	0.
DoQV_cont	real	+	contingency vertical drag, area $(D/q)_{V\rm cont}$	0.
			Derived drag	
DoQ_fus	real		fuselage drag, area $(D/q)_{\rm fus}$	
DoQV_fus	real		fuselage vertical drag, area $(D/q)_{V\rm fus}$	
DoQ_fit	real		fittings and fixtures drag, area $(D/q)_{\rm fit}$	
DoQ_rb	real		rotor-body interference drag, area $(D/q)_{\rm rb}$	
prop_flow(3)	int		propulsion for flow control (group (1 engine, 2 jet), number, model)	

DoQ_cont calculated if total drag fixed (Aircraft FIX_drag); otherwise input
DoQV_cont calculated if total download fixed (Aircraft FIX_DL); otherwise input

		+	Weight	
Weight	Weight		weight statement (component)	
		+	fuselage group	
MODEL_weight	int	+	fuselage group model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWbody	real	+	basic body	0.
dWmar	real	+	body marinization	0.
dWpress	real	+	pressurization	0.
dWcrash	real	+	body crashworthiness	0.
dWftfold	real	+	tail fold	0.
dWfwfold	real	+	wing fold	0.
WFuse	WFuse		AFFD model	
		+	Technology Factors	
TECH_body	real	+	basic body $\chi_{\rm basic}$	1.0
TECH_mar	real	+	body marinization $\chi_{\rm mar}$	1.0
TECH_press	real	+	pressurization $\chi_{\rm press}$	1.0
TECH_crash	real	+	body crashworthiness $\chi_{\rm cw}$	1.0
TECH_ftfold	real	+	tail fold $\chi_{\rm tfold}$	1.0
TECH_fwfold	real	+	wing fold $\chi_{\rm wfold}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

Chapter 40

Structure: AFuse

Variable	Type		Description	Default
		+	Aerodynamics, Standard Model	
AoA_zl	real	+	zero lift angle of attack α_{zl} (deg)	0.
AoA_max	real	+	angle of attack for maximum lift $\alpha_{\max}$ (deg)	10.
		+	lift	
SET_lift	int	+	specification (1 fixed, L/q; 2 scaled, C_L)	2
dLoQda	real	+	lift slope, $d(L/q)/d\alpha$ (per rad)	0.
dCLda	real	+	lift slope, $C_{L\alpha} = dC_L/d\alpha$ (per rad; based on wetted area, $L/q = SC_L$)	0.
		+	pitch moment	
SET_moment	int	+	specification (1 fixed, M/q; 2 scaled, C_M)	2
MoQ0	real	+	moment at zero lift, $(M/q)_0$	0.
CM0	real	+	moment at zero lift, C_{M0} (based on wetted area and fuselage length, $M/q = S\ell C_M$)	0.
dMoQda	real	+	moment slope, $d(M/q)/d\alpha$ (per rad)	0.
dCMda	real	+	moment slope, $C_{M\alpha} = dC_M/d\alpha$ (per rad; based on wetted area and fuselage length, $M/q = S\ell C_M$)	0.
SS_zy	real	+	sideslip angle for zero side force β_{zy} (deg)	0.
SS_max	real	+	sideslip angle for maximum side force $\beta_{\max}$ (deg)	10.
		+	side force	
SET_side	int	+	specification (1 fixed, Y/q; 2 scaled, C_Y)	2
dYoQdb	real	+	side force slope, $d(Y/q)/d\beta$ (per rad)	0.
dCYdb	real	+	side force slope, $C_{Y\beta} = dC_Y/d\beta$ (per rad; based on wetted area, $Y/q = SC_Y$)	0.
		+	yaw moment	
SET_yaw	int	+	specification (1 fixed, N/q; 2 scaled, C_N)	2
NoQ0	real	+	moment at zero lift, $(N/q)_0$	0.
CN0	real	+	moment at zero lift, C_{N0} (based on wetted area and fuselage length, $N/q = S\ell C_N$)	0.
dNoQdb	real	+	moment slope, $d(N/q)/d\beta$ (per rad)	0.
dCNdb	real	+	moment slope, $C_{N\beta} = dC_N/d\beta$ (per rad; based on wetted area and fuselage length, $N/q = S\ell C_N$)	0.

SET_xxx: fixed (use XoQ) or scaled (use CX); other parameter calculated

		+	Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	
CD	real	+	coefficient C_{D0} (based on wetted area, $D/q = SC_D$)	0.005
		+	fixtures and fittings	
SET_Dfit	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ_fit	real	+	area $(D/q)_{\rm fit}$	
CD_fit	real	+	coefficient $C_{D\rm fit}$ (based on wetted area, $D/q = SC_D$)	0.
		+	rotor-body interference	
SET_Drb	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ_rb(nrotormax)	real	+	area $(D/q)_{rb}$	
CD_rb(nrotormax)	real	+	coefficient C_{Drb} (based on wetted area, $D/q = SC_D$)	0.
CD_rb_total	real		total rotor-body interference drag, C_{Drb}	
		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient C_{DV} (based on projected area, $D/q = S_{\rm proj}C_D$)	0.
CDVs	real		$C_{DV}S_{\rm proj}/S_{\rm wet}$	
		+	sideward drag	
SET_Sdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQS	real	+	area $(D/q)_S$	
CDS	real	+	coefficient C_{DS} (based on wetted area, $D/q = SC_D$)	0.
		+	drag variation with angle of attack	
MODEL_drag	int	+	model (0 none, 1 general, 2 quadratic)	2
AoA_Dmin	real	+	angle of attack for fuselage minimum drag $C_{D\rm min}$ (deg)	0.
Kdrag	real	+	drag increment K_d, $\Delta C_D = C_{D0}K_d\|\alpha_e\|^{X_d}$	0.
Xdrag	real	+	drag increment X_d, $\Delta C_D = C_{D0}K_d\|\alpha_e\|^{X_d}$	2.

		+	transition from forward flight drag to vertical drag	
MODEL_trans	int	+	model (1 input transition angle of attack, 2 calculate for quadratic)	1
AoA_tran	real	+	angle of attack for transition α_t (deg)	25.
at	real		angle of attack for transition α_t (deg) (derived)	
Xd	real		exponent X_d (derived)	
		+	Flow Control; $\Delta C_L = C_{L\alpha}(L_{\mu s}\sqrt{C_\mu} + L_{\mu 1}C_\mu + L_{\mu 2}C_\mu^2)$, $\Delta C_{L\max} = X_\mu C_\mu$, $\Delta C_M = M_\mu C_\mu$, $\Delta C_D = D_\mu C_\mu$	
MODEL_flow	int	+	model (0 none)	0
Lmus	real	+	lift $L_{\mu s}$	0.0
Lmu1	real	+	lift $L_{\mu 1}$	0.0
Lmu2	real	+	lift $L_{\mu 2}$	0.0
Xmu	real	+	maximum lift X_μ	1.0
Mmu	real	+	moment M_μ	0.0
Dmu	real	+	drag D_μ	0.0
Cmu_limit	real	+	flow limit $C_{\mu\text{limit}}$	1.0

Chapter 41

Structure: WFuse

Variable	Type		Description	Default
		+	Fuselage Group, NDARC Weight Model	
MODEL_body	int	+	model (1 AFDD84, 2 AFDD82, 3 other)	1
MODEL_other	int	+	model (1 Boeing, GARTEUR (2 air, 3 hel), 4 Tishchenko, 5 Torenbeek, Raymer (6 transport, 7 gen av), 8 generic)	
KIND_ramp	int	+	AFDD: rear cargo ramp (0 none)	0
fLength_crg	real	+	Boeing: cabin length + ramp length + cg range (fraction fuselage length)	0.6
Vdive	real	+	Boeing or Torenbeek or Raymer: design dive speed $V_{\rm dive}$ (knots)	200.
ndoor	int	+	Raymer: number of cargo doors	0
Pdelta	real	+	Raymer: cabin pressure differential (psi)	8.
Kfus	real	+	generic: factor $K_{\rm fus}$	0.
XfusW	real	+	exponent $X_{{\rm fus}W}$	0.
Xfusn	real	+	exponent $X_{{\rm fus}n}$	0.
XfusS	real	+	exponent $X_{{\rm fus}S}$	0.
Xfusl	real	+	exponent $X_{{\rm fus}\ell}$	0.
fWbody_mar	real	+	body weight for marinization $f_{\rm mar}$ (fraction basic body weight)	0.
fWbody_press	real	+	body weight for pressurization $f_{\rm press}$ (fraction basic body weight)	0.
fWbody_crash	real	+	body weight for crashworthiness $f_{\rm cw}$ (fraction body weight)	0.
fWbody_tfold	real	+	tail fold weight $f_{\rm tfold}$ (fraction tail (AFDD84 or other) or body (AFDD82) weight)	0.
fWbody_wfold	real	+	wing fold weight $f_{\rm wfold}$ (fraction wing+tip (AFDD84 or other) or body+tailfold (AFDD82) weight)	0.

AFDD84 (UNIV) is universal body weight model, for tiltrotor and tiltwing as well as for helicopters
AFDD82 (HELO) is helicopter body weight model, should not be used for tiltrotor or tiltwing
dive speed: $V_{\rm max}$ = SLS max speed, Vdive $= 1.25 V_{\rm max}$
fLength_crg = $(\ell_c + \ell_r + \Delta CG)/\ell_{\rm body} \cong$ 1.0 for tandem, 0.3-0.6 for single main rotor (0.7-0.8 with ramp)

typically fWbody_crash = 0.06
typically fWbody_tfold = 0.30 (AFDD84 or other) or 0.05 (AFDD82) for folding tail

		+	Custom Weight Model	
WtParam_fuse(8)	real	+	parameters	0.
			Weight Model Input	
WMTO	real		maximum takeoff weight	
SDGW	real		structural design gross weight	
nz	real		design ultimate flight load factor at SDGW	
Sbody	real		body wetted area	
Lbody	real		fuselage length	
place_LG	int		landing gear placement (1 on body, 2 on wing)	
kind_LG	int		landing gear (0 fixed, 1 retracts)	
WtTail	real		tail weight (for fold)	
WtWing	real		wing weight (for fold)	

Chapter 42

Structure: LandingGear

Variable	Type		Description	Default
		+	Landing Gear	
title	c*100	+	title	
notes	c*1000	+	notes	
		+	Geometry	
loc_gear	Location	+	landing gear location	
d_gear	real	+	distance from bottom of landing gear to WL_gear d_{LG}	0.
place	int	+	placement (1 located on body, 2 located on wing)	1
KIND_LG	int	+	retraction (0 fixed, 1 retracts)	1
speed	real	+	retraction speed (CAS or TAS, knots)	

landing gear location: with HAGL (FltState) determines rotor height above ground level
height rotor = landing gear above ground + hub above landing gear = HAGL + (WL_hub–WL_gear+d_gear)
place: used for weight (fuselage and wing)

Variable	Type		Description	Default
		+	Aerodynamics	
MODEL_aero	int	+	model (0 none, 1 standard)	1
AGear	AGear		standard model	
			Derived drag	
DoQC_LG	real		landing gear cruise drag, area D/q (0 for retractable gear)	
DoQH_LG	real		landing gear helicopter drag, area D/q	

		+	Weight	
Weight	Weight		weight statement (component)	
		+	alighting gear group	
MODEL_weight	int	+	alighting gear group model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWLG	real	+	basic landing gear	0.
dWLGret	real	+	retraction	0.
dWLGcrash	real	+	crashworthiness	0.
WGear	WGear		AFFD model	
		+	Technology Factors	
TECH_LG	real	+	basic landing gear χ_{LG}	1.0
TECH_LGret	real	+	retraction $\chi_{LG\mathrm{ret}}$	1.0
TECH_LGcrash	real	+	crashworthiness $\chi_{LG\mathrm{cw}}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

Chapter 43

Structure: AGear

Variable	Type		Description	Default
		+	Drag, Standard Model	
DoQ	real	+	drag area extended, D/q	

Chapter 44

Structure: WGear

Variable	Type		Description	Default
		+	Landing Gear Group, NDARC Weight Model	
MODEL_LG	int	+	model (1 fraction, 2 parametric rotary wing, 3 parametric fixed wing)	2
nLG	int	+	number of landing gear assemblies N_{LG}	3
fWLG_basic	real	+	basic landing gear weight f_{LG} (fraction maximum takeoff weight)	0.0325
fWLG_ret	real	+	landing gear weight for retraction $f_{LG\text{ret}}$ (fraction basic weight)	0.08
fWLG_crash	real	+	landing gear weight for crashworthiness $f_{LG\text{cw}}$ (fraction basic+retraction weight)	0.14

only MODEL_LG=fraction uses fWLG_basic
typically fWLG_basic = 0.0325 (fraction method)
typically fWLG_ret = 0.08, fWLG_crash = 0.14

Variable	Type		Description	Default
		+	Custom Weight Model	
WtParam_gear(8)	real	+	parameters	0.
			Weight Model Input	
WMTO	real		maximum takeoff weight	
wingload	real		wing loading	

Chapter 45

Structure: Rotor

Variable	Type		Description	Default
		+	Rotor	
title	c*100	+	title	
notes	c*1000	+	notes	
config	c*32	+	Configuration	'main'
rotorconfig	int		configuration (ROTORCONFIG_main, tail, prop)	
isMainRotor	int		main rotor (0 not)	
isAntiQRotor	int		antitorque rotor (0 not)	
isAuxTRotor	int		auxiliary thrust rotor (0 not)	
isVariableDiam	int		variable diameter rotor (0 not)	
isDuctedFan	int		ducted fan (0 not)	
isReactionDrive	int		reaction drive (0 not)	
isMultiRotor	int		multiple rotors (0 not)	
isStoppable	int		stopped rotor (0 not)	
twinrotor	int		configuration (ROTORCONFIG_tandem, coaxial, tiltrotor, not_twin)	

configuration designation: principal designation required, rest identify special characteristics
- principal designation = 'main', 'tail', 'prop'
- antitorque = 'antiQ', 'auxT'
- twin rotor = 'coaxial', 'tandem', 'tiltrotor' (keyword = tan, coax, tilt)
- others = 'variable diameter', 'stop', 'ducted fan', 'reaction drive', 'multirotor' (keyword = var, stop, duct, react, multi)

principal designation determines where weight put in weight statement, and designates main rotors (isMainRotor)
- separately specify appropriate performance and weight models

multiple rotor configurations have special options for geometry and performance
- options defined by variables SET_geom, MODEL_twin, MODEL_int_twin

antitorque or aux thrust rotor has special options for sizing
- options defined by variables SET_rotor, fThrust, Tdesign

reaction drive still requires propulsion group

kRotor	int		rotor number	
		+	Propulsion group	
kPropulsion	int	+	group number	1
KIND_xmsn	int	+	drive system branch (1 primary, 0 dependent)	1
Vtip_ref(ngearmax)	real	+	reference tip speed	
rVtip_ref(ngearmax)	real		ratio to state #1	
Omega_ref	real		reference rotational speed (state #1)	
INPUT_gear	int	+	gear ratio input for dependent branch (1 Vtip_ref, 2 gear)	1
gear(ngearmax)	real	+	gear ratio $r = \Omega_{\rm dep}/\Omega_{\rm prim}$ (ratio rpm to rpm of primary rotor)	1.0
		+	Reaction drive	
r_react	real	+	effective radial station of force (fraction Radius)	1.0
prop_react(3)	int		propulsion for reaction drive (group (1 engine, 2 jet), number, model)	

drive system branch: only one primary rotor per propulsion group
tip speed and gear ratio required for each drive system state
primary: specify Vtip_ref and default tip speeds; $V_{\rm tip-hover}$ = Vtip_ref(1)
dependent: specify gear ratio, or specify Vtip_ref and calculate gear (depend on rotor radius)
can not specify gear ratio if sizing changes dependent rotor $V_{\rm tip}$ (SET_rotor)
if size task changes Vtip_ref(1), then rVtip_ref used to change Vtip_ref(n) for n>1
variable speed transmission: for drive system state STATE_gear_var, gear ratio factor $f_{\rm gear}$ (control) included
when evaluate rotational speed of dependent rotor

reaction drive requires one and only one propulsion system (engine group or jet group)

		+	Default rotor tip speeds (primary rotor)	
INPUT_Vtip	int	+	input form (1 tip speed, 2 hover $V_{\rm tip}$ and rpm ratio)	1
		+	function of flight speed	
nVrpm	int	+	number of speeds (1 constant; ≥ 2 piecewise linear, maximum nvelmax)	1
Vrpm(nvelmax)	real	+	speeds (CAS or TAS)	
		+	tip speed	
Vtip_cruise	real	+	cruise	

Vtip_man	real	+	maneuvering flight	
Vtip_oei	real	+	OEI	
Vtip_xmsn	real	+	transmission sizing	
Vtip(nvelmax)	real	+	function of flight speed	
		+	rpm ratio ($V_{\rm tip}/V_{\rm tip-hover}$)	
fRPM_cruise	real	+	cruise	1.
fRPM_man	real	+	maneuvering flight	1.
fRPM_oei	real	+	OEI	1.
fRPM_xmsn	real	+	transmission sizing	1.
fRPM(nvelmax)	real	+	function of flight speed	1.

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default rotor tip speeds (including conversion): selectable by SET_Vtip of FltState
only for primary rotor; $V_{\rm tip}$ calculated from gear(state) for dependent branch

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		+	Drive system torque limit	
SET_limit_rs	int	+	rotor shaft (0 input, 1 fraction power, 2 fraction drive system limit)	1
Plimit_rs	real	+	rotor shaft power limit $P_{RS\rm limit}$	
fPlimit_rs	real	+	rotor shaft power limit factor	1.
Qlimit_rs	real		rotor shaft torque limit ($P_{RS\rm limit}$ at $\Omega_{\rm ref}$)	

---
drive system torque limit: Size%SET_limit_ds = input (use Plimit_rs) or calculated (from fPlimit_rs)
SET_limit_ds='input': Plimit_rs input
SET_limit_ds≠'input': from rotor power required at transmission sizing flight conditions (DESIGN_xmsn)
rotor shaft: options for SET_limit_ds≠'input'
SET_limit_rs=0: Plimit_rs
SET_limit_rs=1: fPlimit_rs × (rotor P_{req})
SET_limit_rs=2: fPlimit_rs $\times P_{DS\rm limit}$
rotor shaft power limit: corresponds to one rotor
can be used for max effort in flight state (max_quant='Q margin')
can be used for max gross weight in flight condition or mission (SET_GW='maxQ' or 'maxPQ')
always check and print whether exceed torque limit

		+	Parameters	
diskload	real	+	disk loading (lb/ft^2 or N/m^2)	
fArea	real	+	fraction rotor area for reference disk area f_A	
fDGW	real	+	fraction DGW f_W (for disk loading and blade loading)	
fThrust	real	+	thrust factor (antitorque or aux thrust rotor)	1.0
Radius	real	+	radius R	
CWs	real	+	blade loading C_W/σ (thrust-weighted)	
sigma	real	+	solidity $\sigma = Nc/\pi R$ (thrust-weighted)	
Tdesign	real	+	thrust for antitorque or aux thrust rotor	
Pdesign	real	+	power for antitorque or aux thrust rotor	
Ndesign	real	+	rotor speed (rpm) at Pdesign	
SET_thrust	int	+	rotor thrust for disk loading and blade loading (0 default; 1 fDGW*DGW, 2 fThrust*Tdesign)	0
iSET_thrust	int		rotor thrust for disk loading and blade loading (1 from DGW, 2 from Tdesign)	

---

rotor disk loading = T/A; aircraft disk loading = W_D/A_{ref}, $A_{\text{ref}} = \sum(f_A A)$
$W = f_W W_D$ (main rotor) or fThrust*Tdesign (antitorque or aux thrust rotor); can specify using SET_thrust
Tdesign and Pdesign obtained from thrust design conditions and missions (DESIGN_thrust)
if rotor sized from disk loading (SET_rotor='DL+xx+xx'), area = T/diskload
if SET_rotor specify 'Vtip', use Vtip_ref(1)
if SET_rotor not specify 'Vtip', calculate Vtip_ref(1), and then Vtip_ref for dependent rotors
if SET_rotor='CWs+xx+xx', then C_W/σ from fDGW*DGW, takeoff condition, Vtip_ref, and thrust-weighted solidity

for antitorque or aux thrust rotor, need design conditions and missions (DESIGN_thrust) to identify Tdesign
otherwise use fDGW and design gross weight
Tdesign and Pdesign generally calculated (identified as input so inherited by next case)

		+	Geometry	
SET_geom	c*12	+	position (standard, tiltrotor, coaxial, tandem, tailrotor, multicopter)	'std'
KIND_TRgeom	int	+	tiltrotor (1 from clearance, 2 at wing tip, 3 at wing panel edge)	0
		+	twin rotors	
fRadius	real	+	ratio rotor radius to that of other rotor	1.0
otherRotor	int	+	other rotor number	

positionOfRotor	int	+	rotor position (+1/–1 for right/left, lower/upper, front/aft)	0
WingForRotor	int	+	wing number	1
PanelForRotor	int	+	wing panel number	1
clearance_fus	real	+	tiltrotor clearance between rotor and fuselage d_{fus}	0.6
fclearance_fus	real	+	tiltrotor clearance factor	1.0
sep_coaxial	real	+	coaxial rotor separation s (fraction Diameter)	0.08
overlap_tandem	real	+	tandem rotor overlap o (fraction Diameter)	0.25
			derived	
iSET_geom	int		position (SET_geom_standard, tiltrotor, coaxial, tandem, tailrotor, multicopter)	
clearance_calc	real		clearance between rotor and fuselage d_{fus}	
Hsep_twin	real		horizontal separation ℓ (fraction Diameter)	
Vsep_twin	real		vertical separation s (fraction Diameter)	
overlap_twin	real		overlap o (1 – separation/Diameter)	
m_twin	real		overlap area fraction m	
		+	tail rotor	
mainRotor	int	+	main rotor number	1
fRadius_tr	real	+	radius scale factor	1.0
clearance_tr	real	+	clearance between tail rotor and main rotor d_{tr}	0.5
		+	multicopter	
ang_multicopter	real	+	angle ψ (clockwise from forward, deg)	0.
len_multicopter	real	+	arm length ℓ (fraction Radius)	1.5
		+	variable diameter rotor	
SET_VarDiam	int	+	set diameter (1 conversion schedule, 2 function speed)	
fRcruise	real	+	ratio cruise radius to hover radius (variable diameter only)	
		+	rotor stopped as wing	
StopAsWing	int	+	wing number (0 not)	0

SET_geom: calculation override part of location input

SET_geom='tiltrotor': calculate lateral position (BL)

KIND_TRgeom=clearance: from WingForRotor, Width_fus, clearance_fus, fclearance_fus

KIND_TRgeom=wing tip: from WingForRotor, wing span

KIND_TRgeom=wing panel edge: from WingForRotor, PanelForRotor, panel edge and wing span

positionOnRotor specifies right or left position

BL or YoL in loc_pylon, loc_pivot, loc_naccg is relative calculated loc_rotor BL

SET_geom='coaxial': calculate position from sep_coaxial
same sep_coaxial for otherRotor, positionOnRotor specifies lower or upper position
loc_rotor (SL,BL,WL or XoL,YoL,ZoL) is midpoint between hubs
loc_pylon (SL,BL,WL or XoL,YoL,ZoL) is relative calculated loc_rotor
SET_geom='tandem': calculate longitudinal position (SL) from overlap_tandem
same overlap_tandem for otherRotor, positionOnRotor specifies front or aft position
loc_rotor (SL or XoL only) is midpoint between hubs
loc_pylon SL or XoL is relative calculated loc_rotor
SET_geom='tailrotor': calculate longitudinal position (SL) from clearance_tr, mainRotor
loc_pylon SL or XoL is relative calculated loc_rotor
SET_geom='multicopter': calculate longitudinal and lateral position from ang_multicopter, len_multicopter
loc_rotor (SL,BL or XoL,YoL) is center of rotors
loc_pylon (SL,BL,WL or XoL,YoL,ZoL) is relative calculated loc_rotor
ang_multicopter also used for Aircraft%config='multicopter' to define control
if rotor number ≤ 2 and positionOnRotor=0: first rotor is right/lower/front, second rotor is left/upper/aft
sizing:
if SET_rotor='ratio', Radius=fRadius*Radius(otherRotor); otherRotor not SET_rotor='ratio'
twin rotors: config identify as twin rotor
antitorque: config identify as antitorque rotor
if SET_rotor='scale', Radius=fRadius_tr*(main rotor Radius)*function(DiskLoad)
variable diameter: Radius is hover or reference radius; can be commanded by aircraft controls
conversion schedule: R =Radius in hover and helicopter mode ($V \leq V_{\text{conv}-\text{hover}}$)
R =Radius*fRcruise in cruise mode ($V \geq V_{\text{conv}-\text{cruise}}$); linear with V in conversion mode
function of speed: use nVdiam, fdiam, Vdiam to calculate R

stoppable rotor: zero rotor flapping, forces, and power when stopped
stopped (FltAircraft%STOP_rotor=1) uses stopped rotor hub and blade drag
stopped and stowed (FltAircraft%STOP_rotor=2) uses stowed rotor hub drag
stopped as wing (FltAircraft%STOP_rotor=3) uses wing aero (wing number StopAsWing) with zero hub drag

		+	Geometry	
rotate	int	+	direction of rotation (1 counter-clockwise, –1 clockwise)	1
nBlade	int	+	number of blades N	
		+	planform and twist	
SET_chord	int	+	chord distribution (1 linear from fTWsigma, 2 linear from taper, 3 nonlinear from fchord)	1
fTWsigma	real	+	ratio thrust-weighted solidity to geometric solidity $f = \sigma_t/\sigma_g$	1.
taper	real	+	taper ratio t (tip chord/root chord)	1.
SET_twist	int	+	twist distribution (1 linear from twistL, 2 nonlinear from twist)	1
twistL	real	+	linear twist θ_L (deg, root to tip)	-10.
nprop	int	+	number of radial stations (maximum nrmax)	2
rprop(nrmax)	real	+	radial stations (r_{root}/R)	
fchord(nrmax)	real	+	chord distribution $c(r)/c_{\text{ref}}$	1.
twist(nrmax)	real	+	twist $\theta_{tw}(r)$ (deg)	
		+	flap dynamics	
KIND_hub	int	+	hub type (1 articulated, 2 hingeless)	1
flapfreq	real	+	first flapwise natural frequency ν (per-rev at hover tip speed)	1.04
conefreq	real	+	coning natural frequency ν (0. to use flapfreq)	0.
gamma	real	+	blade Lock number γ	8.
precone	real	+	precone β_p (deg)	0.
delta3	real	+	pitch-flap coupling δ_3 (deg)	0.
		+	aerodynamics	
dclda	real	+	blade section 2D lift-curve slope $a = c_{\ell\alpha}$ (per-rad)	5.7
tiploss	real	+	tip loss factor B (lift zero from BR to tip)	0.97
xroot	real	+	root cutout (r_{root}/R)	0.1

SET_chord: use one of fTWsigma, taper, or fchord(r); others calculated (including root cutout)
fTWsigma = sigma_tw/sigma_geom
from fTWsigma: calculate equivalent linear taper, and $f_c = c/c_{\text{ref}}$
from taper (linear): calculate fTWsigma, and $f_c = c/c_{\text{ref}}$
from fchord(r): integrate for c_g and c_t, fTWsigma= c_t/c_g, calculate taper, $f_c =$ scaled fchord

SET_twist: use one of twistL or twist(r); other calculated
for nonlinear distribution, twist relative $0.75R$ obtained from input

flap frequency and Lock number are used for flap dynamics and hub moments due to flap
specified for hover radius and rotational speed
KIND_hub determines how flap frequency and hub moment spring vary with rotor speed and R
weight models can have separate blade and hub values for flap frequency

blade Lock number gamma: for SLS density, $a = 5.7$, thrust-weighted chord
SET_Iblade determines whether Lock number input or calculated

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		+	Geometry (for graphics)	
thick	real	+	blade thickness-to-chord ratio	0.12
			Geometry (derived)	
frotate	real		direction of rotation (1 counter-clockwise, –1 clockwise)	
Arotor	real		rotor area (πR^2)	
chord	real		thrust-weighted chord	
sigma_geom	real		solidity $\sigma = Nc/\pi R$; mean geometric chord	
chord_geom	real		mean geometric chord	
AspectRatio	real		aspect ratio, R/chord_geom	
Ablade	real		thrust-weighted blade area	
Ablade_geom	real		geometric blade area	
KP	real		$\tan(\delta_3)$	
fc(nrmax)	real		chord distribution $f_c = c(r)/c_{\text{ref}}$ (scaled to unit thrust-weighted chord)	
tw(nrmax)	real		twist $\theta_{tw}(r)$ (relative $0.75R$)	
gamma_calc	real		blade Lock number γ	
AI_calc	real		autorotation index KE/P	
Iblade	real		blade moment of inertia I_{blade}	
Kflap	real		flap stiffness K_{flap} (KIND_hub = hingeless)	
eflap	real		flap hinge offset e (KIND_hub = articulated)	
Kcone	real		cone stiffness K_{cone} (conefreq input)	
Khub	real		hub moment spring K_{hub}	
		+	Blade element theory solution	
		+	integration	
mr	int	+	number of radial stations (xroot to 1; maximum mrmax)	4
mpsi	int	+	number of azimuth angles (maximum mpsimax)	8

dr	real		radial increment $dr = (1 - \text{xroot})/\text{mr}$	
cspsi(mpsimax)	real		$\cos(\psi_j)$, $\psi_j = j\,\Delta\psi$, $j = 1$ to mpsi ($\Delta\psi = 2\pi/\text{mpsi}$)	
snpsi(mpsimax)	real		$\sin(\psi_j)$, $\psi_j = j\,\Delta\psi$, $j = 1$ to mpsi ($\Delta\psi = 2\pi/\text{mpsi}$)	
		+	Geometry	
loc_rotor	Location	+	hub location	
loc_pylon	Location	+	pylon location	
loc_pivot	Location	+	pivot location	
loc_naccg	Location	+	nacelle cg location	
direction	c*16	+	nominal orientation ('+x', '–x', '+y', '–y', '+z', '–z'; 'main' (–z), 'tail' (ry), 'prop' (x))	'main'
KIND_tilt	int	+	shaft control (0 fixed shaft, 1 incidence, 2 cant, 3 both controls)	0
		+	orientation of rotor shaft	
incid_hub	real	+	incidence θ_h (deg)	0.
cant_hub	real	+	cant angle ϕ_h (deg)	0.
		+	orientation of pivot axes	
dihedral_pivot	real	+	pivot dihedral angle ϕ_p (deg)	
pitch_pivot	real	+	pivot pitch angle θ_p (deg)	
sweep_pivot	real	+	pivot sweep angle ψ_p (deg)	
		+	reference shaft control	
incid_ref	real	+	incidence i_{ref} (deg)	0.
cant_ref	real	+	cant angle c_{ref} (deg)	0.
		+	moving weight for cg shift	
SET_Wmove	int	+	weight (1 wing tip weight, 2 W_{gbrs}, 3 W_{gbrs} and W_{ES})	1
fWmove	real	+	fraction moving weight	1.
dz_hub(3)	real	+	hub position increment due to tilt Δz^F_{hub} (SL/BL/WL)	0.
			Derived geometry	
iDirection	int		nominal orientation (1, –1, 2, –2, 3, –3, –3, r2, 1)	
axis_incid	int		axis incidence (±123)	
axis_cant	int		axis cant (±123)	
KIND_incid	int		incidence (0 fixed, 1 controlled)	
KIND_cant	int		cant angle (0 fixed, 1 controlled)	
CPF(3,3)	real		pivot axes relative airframe, C^{PF}	
CFP(3,3)	real		pivot axes relative airframe, C^{FP}	
WCHF(3,3)	real		WC^{HF} (C^{SF} for reference control)	
CSF(3,3)	real		rotor shaft relative airframe, C^{SF} (zero shaft control)	

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loc_naccg, loc_pivot, orientation of pivot axes, and reference shaft control angles not used for KIND_tilt=fixed shaft for tiltrotor, locations and orientation specified in helicopter mode, so incid_ref = 90
SET_Wmove: cg shift calculated using incidence and cant rotation of loc_naccg relative loc_pivot
moving weight fWmove*Wmove, Wmove = Wtip_total/nRotorOnWing or w/N_{rotor}
$w = W_{gbrs}$ (drive system) or $W_{gbrs} + \sum(W_{ES})$ (drive system and engine system)

		+	Controls	
KIND_control	int	+	rotor control mode (1 thrust and TPP, 2 thrust and NFP, 3 pitch and TPP, 4 pitch and NFP)	1
KIND_cyclic	int	+	cyclic input (1 tip-path-plane tilt, 2 hub moment, 3 lift offset)	1
KIND_coll	int	+	collective input (1 thrust, 2 C_T/σ)	2
SCALE_coll	int	+	scale collective T matrix (0 for none)	1
		+	collective (magnitude of thrust vector)	
INPUT_coll	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_coll(ncontmax,nstatemax)	real	+	control matrix	
nVcoll	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
coll(nvelmax)	real	+	values	
Vcoll(nvelmax)	real	+	speeds (CAS or TAS)	
		+	longitudinal cyclic (tip-path plane tilt or no-feathering plane tilt)	
INPUT_lngcyc	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_lngcyc(ncontmax,nstatemax)	real	+	control matrix	
nVlngcyc	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
lngcyc(nvelmax)	real	+	values	
Vlngcyc(nvelmax)	real	+	speeds (CAS or TAS)	
		+	lateral cyclic (tip-path plane tilt or no-feathering plane tilt)	
INPUT_latcyc	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_latcyc(ncontmax,nstatemax)	real	+	control matrix	
nVlatcyc	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
latcyc(nvelmax)	real	+	values	
Vlatcyc(nvelmax)	real	+	speeds (CAS or TAS)	

		+	incidence i (nacelle tilt)	
INPUT_incid	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax)	real	+	control matrix	
nVincid	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax)	real	+	values	
Vincid(nvelmax)	real	+	speeds (CAS or TAS)	
		+	cant c	
INPUT_cant	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_cant(ncontmax,nstatemax)	real	+	control matrix	
nVcant	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
cant(nvelmax)	real	+	values	
Vcant(nvelmax)	real	+	speeds (CAS or TAS)	
		+	diameter f_{diam} (variable diameter only)	
INPUT_diam	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_diam(ncontmax,nstatemax)	real	+	control matrix	
nVdiam	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
fdiam(nvelmax)	real	+	values	
Vdiam(nvelmax)	real	+	speeds (CAS or TAS)	
		+	gear ratio factor f_{gear} (variable speed transmission only)	
INPUT_fgear	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_fgear(ncontmax,nstatemax)	real	+	control matrix	
nVfgear	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
fgear(nvelmax)	real	+	values	
Vfgear(nvelmax)	real	+	speeds (CAS or TAS)	
		+	reaction drive net force F_{react}	
INPUT_Freact	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_Freact(ncontmax,nstatemax)	real	+	control matrix	
nVFreact	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
Freact(nvelmax)	real	+	values	
VFreact(nvelmax)	real	+	speeds (CAS or TAS)	

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aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to component control, flight state can specify component control value
initial values if control is connected to trim variable; otherwise fixed for flight state

pylon moves with rotor; nontilting part is engine nacelle

		+	Trim Targets	
		+	rotor lift	
nVlift	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	
Klift(nvelmax)	real	+	target	
Vlift(nvelmax)	real	+	speeds (CAS or TAS)	
		+	rotor propulsive force	
nVprop	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	
Kprop(nvelmax)	real	+	target	
Vprop(nvelmax)	real	+	speeds (CAS or TAS)	

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target definition determined by Aircraft%trim_quant
Klift can be fraction total aircraft lift, lift, C_L/σ, or C_T/σ
Kprop can be fraction total aircraft drag, propulsive force $-X$, $-C_X/\sigma$, or $-X/q$)

		+	Rotor Thrust Capability (C_T/σ vs μ)	
		+	sustained	
nsteady	int	+	number of points (maximum 20)	16
mu_steady(20)	real	+	advance ratio	
CTs_steady(20)	real	+	C_T/σ	
		+	transient	
ntran	int	+	number of points (maximum 20)	16
mu_tran(20)	real	+	advance ratio	
CTs_tran(20)	real	+	C_T/σ	

		+	equation, $C_T/\sigma = K_0 - K_1\mu^2$	
K0_limit	real	+	constant K_0	0.17
K1_limit	real	+	constant K_1	0.25

CTs_steady, CTS_tran used to calculate rotor thrust margin, which available for max effort or trim
defaults used if CTs(1)=0.
default CTs_steady = .170,.168,.161,.149,.131,.109,.084,.050,.049,.048,.047,.046,.045,.044,.043,.042
default CTs_tran = .200,.197,.190,.177,.156,.135,.110,.080,.075,.070,.065,.060,.055,.050,.045,.040
default mu_steady = 0.,.10,.20,.30,.40,.50,.60,.70,.71,.72,.73,.74,.75,.76,.77,.78
default mu_tran = 0.,.10,.20,.30,.40,.50,.60,.70,.72,.74,.76,.78,.80,.82,.84,.86

		+	Performance	
MODEL_perf	int	+	power model (1 standard, 2 table model)	1
PRotorInd	PRotorInd		standard model, induced power	
PRotorPro	PRotorPro		standard model, profile power	
PRotorTab	PRotorTab		table model	
MODEL_Ftpp	int	+	inplane forces, tip-path plane axes (1 neglect, 2 blade-element theory)	2
MODEL_Fpro	int	+	inplane forces, profile (1 simplified, 2 blade element theory, 3 neglect)	2

if thrust and TPP command, and neglect inplane forces relative TPP, then pitch control angles not required

		+	Interference	
MODEL_int	int	+	model (0 none, 1 standard, 2 with transition)	1
		+	transition	
Vint_low	real	+	low velocity (knots)	0.
Vint_high	real	+	high velocity (knots)	0.
IRotor	IRotor		standard model	

Kint=0 to suppress interference at component; MODEL_int=0 for no interference at all
with transition: interference factors linearly vary from Kint at $V \leq$ Vint_low to 0 at $V \geq$ Vint_high

		+	Geometry	
SET_aeroaxes	int	+	hub/pylon aerodynamic axes (0 input pitch, 1 helicopter, 2 propeller or tiltrotor)	1
pitch_aero	real	+	pitch relative shaft axes $\theta_{\rm ref}$, $C^{BS} = Y_{-\theta_{\rm ref}}$	0.
SET_Spylon	int	+	pylon wetted area (1 fixed, input Swet; 2 scaled, W_{gbrs}; 3 scaled, W_{gbrs} and W_{ES})	2
Swet_pylon	real	+	area $S_{\rm pylon}$	0.
kSwet_pylon	real	+	factor, $k = S_{\rm pylon}/(w/N_{\rm rotor})^{2/3}$ (Units_Dscale)	1.0
SET_Sduct	int	+	duct area (1 fixed, input S_duct; 2 scaled, from fLength_duct)	2
S_duct	real	+	area $S_{\rm duct}$	0.
fLength_duct	real	+	duct length (fraction rotor radius)	1.2
SET_Sspin	int	+	spinner wetted area (1 fixed, input Swet; 2 scaled, from fSwet)	2
Swet_spin	real	+	area $S_{\rm spin}$	0.
fSwet_spin	real	+	factor, $k = S_{\rm spin}/A_{\rm spin}$	1.0
fRadius_spin	real	+	spinner radius (fraction rotor radius)	0.
			Derived geometry	
CBS(3,3)	real		pylon axes relative shaft, C^{BS}	
CBF(3,3)	real		pylon axes relative airframe, C^{BF} (zero shaft control)	
Radius_spin	real		spinner radius $R_{\rm spin}$	

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only SET_aeroaxes=input uses pitch_aero; pitch_aero=180 for helicopter, 90 for propeller

SET_Spylon, pylon wetted area: input (use Swet_pylon) or calculated (from kSwet_pylon)
units of kSwet are ft^2/lb$^{2/3}$ or m^2/kg$^{2/3}$
$w = W_{gbrs}$ (drive system) or $W_{gbrs} + \sum W_{ES}$ (drive system and engine system)
pylon wetted area used for pylon drag
rotor pylon must be consistent with engine group nacelle

SET_Sduct, duct area: input (use S_duct) or calculated (from fLength_duct)
$S_{\rm duct} = (2\pi R)\ell_{\rm duct}$, $\ell_{\rm duct}$ =fLength_duct*R; used for drag (wetted area $2S_{\rm duct}$) and weight

SET_Sspin, spinner wetted area: (use Swet_spin) or calculated (from fSwet_spin)
$A_{\rm spin} = \pi R_{\rm spin}^2$ = spinner frontal area (from fRadius_spin*R); spinner radius used for drag and weight

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		+	Drag	
MODEL_drag	int	+	model (0 none, 1 standard)	1
Idrag	real	+	incidence angle for helicopter nominal drag (deg; 0 for not tilt)	0.
DRotor	DRotor		standard model	
			Derived drag	
DoQC_hub	real		hub cruise drag, area $(D/q)_{\rm hub}$	
DoQH_hub	real		hub helicopter drag, area $(D/q)_{\rm hub}$	
DoQV_hub	real		hub vertical drag, area $(D/q)_{\rm hub}$	
DoQC_pylon	real		pylon cruise drag, area $(D/q)_{\rm pylon}$	
DoQH_pylon	real		pylon helicopter drag, area $(D/q)_{\rm pylon}$	
DoQV_pylon	real		pylon vertical drag, area $(D/q)_{\rm pylon}$	
DoQC_duct	real		duct cruise drag, area $(D/q)_{\rm duct}$	
DoQH_duct	real		duct helicopter drag, area $(D/q)_{\rm duct}$	
DoQV_duct	real		duct vertical drag, area $(D/q)_{\rm duct}$	
DoQ_spin	real		spinner drag, area $(D/q)_{\rm spin}$	
Swet_rotor	real		total wetted area $S_{\rm wet}$	
		+	Download and blockage	
MODEL_download	int	+	model (0 none, 1 blockage, 2 download, 3 both)	0
download	real	+	download $DL = \Delta T/T$	0.
blockage	real	+	blockage $B = \Delta T/T$	0.
muDL	real	+	advance ratio μ_{DL} (0. for no correction)	0.16
zDL	real	+	height above ground $(z_g/D)_{DL}$ (fraction diameter, 0. for no correction)	0.41
aDL	real	+	forward flight constant a_{DL}	1.04
bDL	real	+	ground effect constant b_{DL}	0.23

---

download: rotor induced and profile power evaluated at thrust increased by $f_{DL} = 1/(1 - \Delta T/T)$
blockage: force acting on aircraft includes $f_B = (\Delta T/T)T$ opposing thrust
download DL and blockage B are for hover, out of ground effect
download and blockage zero for $\mu > \mu_{DL}$ or $z_g/D < (z_g/D)_{DL}$

		+	Weight	
Weight	Weight		weight statement (component)	
		+	rotor group (or empennage or propulsion group)	
MODEL_weight	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWblade	real	+	blade	0.
dWhub	real	+	hub and hinge	0.
dWshaft	real	+	inter-rotor shaft	0.
dWspin	real	+	fairing/spinner	0.
dWrfold	real	+	blade fold	0.
dWtr	real	+	tail rotor	0.
dWaux	real	+	auxiliary thrust	0.
dWrsupt	real	+	rotor support structure	0.
dWduct	real	+	duct	0.
WRotor	WRotor		NDARC model	
SET_Iblade	int	+	blade moment of inertia (0 from Lock number, 1 from blade wt, 2 tip wt from Lock number, 3 tip wt from AI)	1
AI	real	+	autorotation index $KE/P = \frac{1}{2} N_{\text{blade}} I_{\text{blade}} \Omega^2 / P$ (sec)	3.0
Wblade_tip	real	+	tip weight (per blade)	0.
rWblade_tip	real	+	location tip weight (fraction blade radius)	0.9
fWblade_tip	real	+	distributed weight for centrifugal force (fraction Wblade_tip)	1.0
rblade	real	+	radius of gyration for distributed mass (fraction blade radius)	0.6
xWblade	real	+	blade weight (fraction total tail rotor or auxiliary thrust rotor weight)	0.55
Wblade	real		blade weight (all blades; required for drive system weight)	
Wtip	real		weight on wing tip (required for tiltrotor wing weight)	
		+	Technology Factors	
TECH_blade	real	+	blade weight χ_{blade}	1.0
TECH_hub	real	+	hub and hinge weight χ_{hub}	1.0
TECH_shaft	real	+	inter-rotor shaft χ_{shaft}	1.0
TECH_spin	real	+	fairing/spinner weight χ_{spin}	1.0
TECH_rfold	real	+	blade fold weight χ_{fold}	1.0
TECH_tr	real	+	tail rotor weight χ_{tr}	1.0
TECH_aux	real	+	auxiliary thrust weight χ_{at}	1.0
TECH_rsupt	real	+	rotor support structure weight χ_{supt}	1.0
TECH_duct	real	+	duct weight χ_{duct}	1.0

weight model result multiplied by technology factor and increment added:

Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

blade weight: $W_{\text{blade}} = \chi_{\text{blade}} w_{\text{blade}} + dW_{\text{blade}} + (1+f)W_{\text{tip}} N_{\text{blade}}$

SET_Iblade: calculate blade moment of inertia Iblade

0 from Lock number gamma, independent of blade weight

1 from blade weight

2 from Lock number gamma, tip weight Wblade_tip calculated from Iblade

3 from autorotation index AI, tip weight Wblade_tip calculated from Iblade

for tail rotor or aux thrust weight model (MODEL_config = 2 or 3), blade weight $W_{\text{blade}} =$ xWblade*W_{tr} or xWblade*W_{at}

rotor weight = blade + hub + spinner + fold + shaft + support + duct

rotor config determines where weight put in weight statement

main rotor: rotor group

tail rotor: empennage group (tail rotor)

propeller: propulsion group (propeller/fan installation)

Chapter 46

Structure: PRotorInd

Variable	Type		Description	Default
		+	Rotor Induced Power, Standard Energy Performance Method	
MODEL_ind	int	+	model (0 none, 1 constant, 2 standard)	2
		+	induced velocity factors (ratio to momentum theory induced velocity)	
Ki_hover	real	+	hover κ_{hover}	1.12
Ki_climb	real	+	axial climb κ_{climb}	1.08
Ki_prop	real	+	axial cruise (propeller) κ_{prop}	2.0
Ki_edge	real	+	edgewise flight (helicopter) κ_{edge}	2.0
		+	variation with thrust	
CTs_Hind	real	+	$(C_T/\sigma)_{\text{ind}}$ for hover κ_h variation	0.08
kh1	real	+	coefficient k_{h1} for κ_h	0.
kh2	real	+	coefficient k_{h2} for κ_h	0.
Xh2	real	+	exponent X_{h2} for κ_h	2.
CTs_Pind	real	+	$(C_T/\sigma)_{\text{ind}}$ for axial κ_p variation	0.08
kp1	real	+	coefficient k_{p1} for κ_p	0.
kp2	real	+	coefficient k_{p2} for κ_p	0.
Xp2	real	+	exponent X_{p2} for κ_p	2.
CTs_Tind	real	+	$(C_T/\sigma)_{\text{ind}}$ for edgewise κ_e variation	0.08
kt1	real	+	coefficient k_{t1} for κ_e	0.
kt2	real	+	coefficient k_{t2} for κ_e	0.
Xt2	real	+	exponent X_{t2} for κ_e	2.
		+	variation with shaft angle	
kpa	real	+	coefficient $k_{p\alpha}$ for κ_p	0.
Xpa	real	+	exponent $X_{p\alpha}$ for κ_p	2.
		+	variation with propulsive force	
kpx	real	+	coefficient k_{px} for κ_p	0.
Xpx	real	+	exponent X_{px} for κ_p	1.
		+	axial flight transition	
Maxial	real	+	constant M_{axial} from hover to climb	1.176

Xaxial	real	+	exponent $X_{\rm axial}$ from hover to climb	0.65
mu_axtran	real	+	advance ratio $\mu_{z\rm tran}$ from hover to axial	0.
		+	variation with axial velocity	
mu_prop	real	+	advance ratio $\mu_{z\rm prop}$ for Ki_prop	1.0
ka1	real	+	coefficient k_{a1} for $\kappa(\mu_z)$ (linear)	0.
ka2	real	+	coefficient k_{a2} for $\kappa(\mu_z)$ (quadratic)	0.
ka3	real	+	coefficient k_{a3} for $\kappa(\mu_z)$	0.
Xa	real	+	exponent X_a for $\kappa(\mu_z)$	4.5
		+	variation with edgewise velocity	
MODEL_edge	int	+	model for edgewise κ relative axial κ (0 replace, 1 sum)	0
mu_edge	real	+	advance ratio $\mu_{\rm edge}$ for Ki_edge	0.35
ke1	real	+	coefficient k_{e1} for $\kappa(\mu)$ (linear)	0.8
ke2	real	+	coefficient k_{e2} for $\kappa(\mu)$ (quadratic)	0.
ke3	real	+	coefficient k_{e3} for $\kappa(\mu)$	1.
Xe	real	+	exponent X_e for $\kappa(\mu)$	4.5
kea	real	+	variation with rotor drag $k_{e\alpha}$	0.
		+	variation with lift offset	
ko1	real	+	coefficient k_{o1} for $f_{\rm off}$	0.
ko2	real	+	factor k_{o2} for $f_{\rm off}$	8.
Ki_min	real	+	minimum $\kappa_{\rm min}$	1.
Ki_max	real	+	maximum $\kappa_{\rm max}$	10.
fedge	real		edgewise scale factor S	
fprop	real		axial scale factor S	

MODEL_ind=constant uses only Ki_hover, Ki_prop, Ki_edge
nonzero values of Ki in FltState supersede calculated value

		+	Climb power	
MODEL_climb	int	+	model (0 for no climb power increment, 1 vertical, 2 edgewise, 3 both)	0
		+	vertical flight	
nclimb_vert	int	+	number of climb values (maximum 20)	
Vclimb_vert(20)	real	+	climb speed V_c/v_h	
fclimb_vert(20)	real	+	climb power factor f	

		+	edgewise forward flight	
nclimb_edge	int	+	number of climb values (maximum 20)	
Vclimb_edge(20)	real	+	climb speed V_c/v_h	
fclimb_edge(20)	real	+	climb power factor f	

climb power factor $f(V_c/v_h)$ gives $P_{\rm climb} - P_{\rm level} = TV_c f$
including TV_c and effect of climb on induced and profile power
intended for use with table model for level flight power

		+	Momentum theory	
MODEL_grad	int	+	inflow gradient in forward flight (0 none, 1 White and Blake, 2 Coleman and Feingold)	1
fGradx	real	+	longitudinal gradient factor f_x	1.
fGrady	real	+	lateral gradient factor f_y	1.
fGradm	real	+	hub moment inflow gradient factor f_m	1.
		+	Ground effect	
MODEL_GE	int	+	model (0 none, 1 Cheeseman, 2 BE Cheeseman, 3 Law, 4 Hayden, 5 Zbrozek, 6 Maryland, 7 T table, 8 P table)	3
Cge	real	+	effective height correction C_g	1.
		+	table	
KIND_GEtable	int	+	table kind (2 2D, 3 3D)	2
nCTsGE	int	+	number of C_T/σ values (maximum ngetabmax)	0
nhGE	int	+	number of h/D values (maximum ngetab2max)	0
nMtipGE	int	+	number of $M_{\rm tip}$ values (maximum ngetab2max)	0
CTsGE(ngetabmax)	real	+	blade loading C_T/σ	
hGE(ngetab2max)	real	+	rotor height above ground h/D	
MtipGE(ngetab2max)	real	+	rotor tip Mach number $M_{\rm tip}$	
xGE(ngetabmax,ngetab2max)	real	+	ground effect factor $\kappa_g = x(C_T/\sigma, h/D)$ or $f_g = x(C_T/\sigma, h/D)$	
xGE3(ngetabmax,ngetab2max,ngetab2max)	real	+	ground effect factor $\kappa_g = x(C_T/\sigma, h/D, M_{\rm tip})$ or $f_g = x(C_T/\sigma, h/D, M_{\rm tip})$	

MODEL_GE: table options for $\kappa_g = T/T_\infty$ or $f_g = P/P_\infty$
as function of blade loading C_T/σ and rotor height above ground h/D (fraction rotor diameter),
and perhaps tip Mach number $M_{\rm tip}$

Cge: for tiltrotors, typically $C_g = 0.5$; smaller effective height accounting for increased influence of ground compared to isolated rotor

		+	Ducted fan	
MODEL_duct	int	+	model (1 specify area ratio, 2 specify thrust ratio)	1
fDuctA	real	+	area ratio f_A (fan area/far wake area)	1.
fDuctT	real	+	thrust ratio f_T (rotor thrust/total thrust)	0.5
fDuctVx	real	+	velocity ratio f_{Vx} (fan edgewise velocity/free stream velocity)	1.
fDuctVz	real	+	velocity ratio f_{Vz} (fan axial velocity/free stream velocity)	1.
eta_duct	real	+	duct efficiency η_D (total pressure loss through duct)	1.

ducted fan model used only if config='duct'

		+	Twin rotors	
MODEL_twin	c*12	+	model (based on config, none, side-by-side, coaxial, tandem, multirotor)	'config'
Kh_twin	real	+	ideal induced velocity correction for hover $\kappa_{h\rm twin}$	1.00
Kp_twin	real	+	ideal induced velocity correction for propeller $\kappa_{p\rm twin}$	1.00
Kf_twin	real	+	ideal induced velocity correction for forward flight $\kappa_{f\rm twin}$	0.85
Cind_twin	real	+	constant C in axial to forward flight transition	1.0
Caxial_twin	real	+	constant C_a in hover to propeller transition	1.0
A_coaxial	real	+	coaxial rotor nonuniform disk loading factor $\bar{\alpha}$	1.05
xh_multi(nrotormax)	real	+	multirotor thrust factor x_h for hover	1.0
xp_multi(nrotormax)	real	+	multirotor thrust factor x_p for propeller	1.0
xf_multi(nrotormax)	real	+	multirotor thrust factor x_f for forward flgiht	1.0

		Derived twin rotors
iMODEL_twin	int	model (MODEL_twin_none, sidebyside, coaxial, tandem, multirotor)
xh	real	thrust factor x_h, hover
xp	real	thrust factor x_p, propeller
xf1	real	thrust factor x_{f1}, forward flight, this rotor
xf2	real	thrust factor x_{f2}, forward flight, other rotor

MODEL_twin: 'config', 'none', 'side-by-side' or 'tiltrotor', 'coaxial', 'tandem', or 'multirotor'
'config' must identify rotor as twin or multiple rotors
coaxial: MODEL_twin='coaxial' (use A_coaxial; Kh_twin not used)
or MODEL_twin='tandem' with zero horizontal separation (typically Kh_twin=0.90)
coaxial and tandem: Kf_twin = 0.88 to 0.81 for rotor separation $0.06D$ to $0.12D$
thrust factors x calculated for twin rotors, input for multiple rotors
correction factors and transition constants ($\kappa_{\rm twin}$, C, C_a) used for twin or multiple rotors

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Chapter 47

Structure: PRotorPro

Variable	Type		Description	Default
		+	Rotor Profile Power, Standard Energy Performance Method	
		+	Technology factor	
TECH_drag	real	+	profile power χ	1.0
Re_ref	real	+	Reference Reynolds number Re_{ref} (0. for no correction)	0.
X_Re	real	+	exponent for Reynolds number correction X_{Re}	0.2
MODEL_basic	int	+	Basic model $c_{d\text{basic}}$ (0 none, 1 array, 2 equation)	2
		+	array (c_d vs thrust-weighted C_T/σ)	
ncd	int	+	number of points (maximum 24)	24
CTs_cd(24)	real	+	blade loading	
cd(24)	real	+	drag coefficient	
		+	equation	
CTs_Dmin	real	+	$(C_T/\sigma)_{D\min}$ for minimum profile drag ($\Delta = \lvert C_T/\sigma - (C_T/\sigma)_{D\min}\rvert$)	0.07
d0_hel	real	+	coefficient $d_{0\text{hel}}$ in drag, $c_{dh} = d_{0\text{hel}} + d_{1\text{hel}}\Delta + d_{2\text{hel}}\Delta^2 + \Delta c_{d\text{sep}}$ (hover/edgewise)	0.009
d1_hel	real	+	coefficient $d_{1\text{hel}}$ in drag (hover/edgewise)	0.
d2_hel	real	+	coefficient $d_{2\text{hel}}$ in drag (hover/edgewise)	0.5
d0_prop	real	+	coefficient $d_{0\text{prop}}$ in drag, $c_{dp} = d_{0\text{prop}} + d_{1\text{prop}}\Delta + d_{2\text{prop}}\Delta^2 + \Delta c_{d\text{sep}}$ (axial)	0.009
d1_prop	real	+	coefficient $d_{1\text{prop}}$ in drag (axial)	0.
d2_prop	real	+	coefficient $d_{2\text{prop}}$ in drag (axial)	0.5
dprop	real	+	variation with shaft angle, coefficient $d_{p\alpha}$ for c_{dp}	0.
Xprop	real	+	variation with shaft angle, exponent $X_{p\alpha}$ for c_{dp}	2.
CTs_sep	real	+	$(C_T/\sigma)_{\text{sep}}$ for separation ($\Delta c_{d\text{sep}} = d_{\text{sep}}(\lvert C_T/\sigma\rvert - (C_T/\sigma)_{\text{sep}})^{X_{\text{sep}}}$)	0.07
dsep	real	+	factor d_{sep} in drag increment	4.0
Xsep	real	+	exponent X_{sep} in drag increment	3.0
df1	real	+	variation with edgewise velocity, coefficient d_{f1}	0.
df2	real	+	variation with edgewise velocity, coefficient d_{f2}	0.
Xf	real	+	variation with edgewise velocity, exponent X_f	2.

dz1	real	+	variation with axial velocity, coefficient d_{z1}	0.
dz2	real	+	variation with axial velocity, coefficient d_{z2}	0.
Xz	real	+	variation with axial velocity, exponent X_z	2.

default array (cd(1)=0.): $C_T/\sigma = 0.$ to 0.23 (uniform increments)
cd = .01100,.01075,.01025,.01000,.01010,.01070,.01050,.00975,.00925,.00926,.00938,.00977,
.01048,.01152,.01336,.01593,.01920,.02381,.03014,.04000,.08000,.16000,.32000,1.0000

nonzero values of cdo in FltState supersede calculated cdmean

MODEL_stall	int	+	Stall model $c_{d\text{stall}}$ (0 none)	1
		+	C_T/σ at stall ($\Delta_s = \lvert C_T/\sigma \rvert - (f_s/f_\alpha f_{\text{off}})(C_T/\sigma)_s$, $\Delta c_d = d_{s1}\Delta_s^{X_{s1}} + d_{s2}\Delta_s^{X_{s2}}$)	
nstall	int	+	number of points (maximum 20)	10
mu_stall(20)	real	+	advance ratio V/V_{tip}	
CTs_stall(20)	real	+	$(C_T/\sigma)_s$	
fstall	real	+	constant f_s in stall drag increment	1.0
dstall1	real	+	factor d_{s1} in stall drag increment	2.
dstall2	real	+	factor d_{s2} in stall drag increment	40.
Xstall1	real	+	exponent X_{s1} in stall drag increment	2.0
Xstall2	real	+	exponent X_{s2} in stall drag increment	3.0
		+	variation with lift offset	
do1	real	+	coefficient d_{o1} for f_{off}	0.
do2	real	+	factor d_{o2} for f_{off}	8.
dsa	real	+	variation with rotor drag $d_{s\alpha}$	0.

default used if CTs_stall(1)=0.
default CTs_stall = 0.17,0.16,0.15,0.14,0.13,0.12,0.11,0.10,0.10,0.10
default mu_stall = 0.00,0.05,0.10,0.15,0.20,0.25,0.30,0.35,0.40,0.80

MODEL_comp	int	+	Compressibility model $c_{d\text{comp}}$ (0 none, 1 drag divergence, 2 similarity, 3 tip Mach number)	1
MODEL_comp_ff	int	+	compressibility increment (0 only used for hover or axial flight)	1
		+	similarity model	
fSim	real	+	factor f	1.0
thick_tip	real	+	blade tip thickness-to-chord ratio τ	0.08
		+	drag divergence model ($\Delta_m = M_{at} - M_{dd}$, $\Delta c_d = d_{m1}\Delta_m + d_{m2}\Delta_m^{X_m}$)	
dm1	real	+	coefficient d_{m1} in drag increment	0.056
dm2	real	+	coefficient d_{m2} in drag increment	0.416
Xm	real	+	exponent X_m in drag increment	2.0
		+	drag divergence Mach number ($M_{dd} = \mathsf{Mdd0} - \mathsf{Mddcl}\ c_\ell$)	
Mdd0	real	+	M_{dd0} at zero lift	0.88
Mddcl	real	+	derivative with lift $\kappa = \partial M_{dd}/\partial c_\ell$	0.16
		+	tip Mach number model	
dmt	real	+	coefficient d_{mt}	
Mtip_limit	real	+	tip Mach number limit M_{tiplimit}	
CT_limit	real	+	thrust coefficient limit $C_{T\text{limit}}$	
Mtip_ref	real	+	reference tip Mach number M_{tipref}	
MODEL_propeff	int	+	Propulsive force efficiency (0 none)	0
DoQ_ref	real	+	reference propulsive force $(D/q)_{\text{ref}}$	
nCTs_eff	int	+	number of blade loading values (maximum 20)	
nV_eff	int	+	number of rotor velocity values (maximum 20)	
CTs_eff(20)	real	+	blade loading C_T/σ	
V_eff(20)	real	+	rotor velocity V/V_{tip}	
propeff(20,20)	real	+	efficiency for propulsive force increment $\eta(C_T/\sigma, V/V_{\text{tip}})$	

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propeff: efficiency η gives $\Delta P_o = V\ \Delta D(1/\eta - 1)$
DoQ_ref corresponds to baseline profile and induced power models
intended for use with table model for power at baseline propulsive force

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Chapter 48

Structure: PRotorTab

Variable	Type		Description	Default
		+	Performance, Table Method	
MODEL_indTab	int	+	induced power model (0 standard, 1 table, 2 table with equations)	1
nvar_ind	int	+	number independent variables (1 to 3)	0
var_ind(3)	c*12	+	variables	' '
nv_ind(3)	int	+	number of variable values (maximum ntablemax)	0
v_ind(ntablemax,3)	real	+	independent variable	
MODEL_proTab	int	+	profile power model (0 standard, 1 table, 2 table with equations)	1
KIND_proTab	int	+	profile power model (0 standard, 1 table $c_{d\text{mean}}$, 2 table $c_{d\text{mean}}F = 8C_{Po}/\sigma$)	1
nvar_pro	int	+	number independent variables (1 to 3)	0
var_pro(3)	c*12	+	variables	' '
nv_pro(3)	int	+	number of variable values (maximum ntablemax)	0
v_pro(ntablemax,3)	real	+	independent variable	
MODEL_geTab	int	+	ground effect model (0 inflow, 1 table thrust, 2 table power)	0
		+	table	
Ki(ntablemax,ntablemax,ntablemax)				
	real	+	induced power factor κ	
cdo(ntablemax,ntablemax,ntablemax)				
	real	+	profile power mean c_d	
			Derived	
ivar_ind(3)	int		induced power variables (tablevar_V, Vh, mu, muz, alpha, muTPP, muzTPP, alphaTPP, CTs, Mx, Mtip, Mat)	
ivar_pro(3)	int		profile power variables (tablevar_V, Vh, mu, muz, alpha, muTPP, muzTPP, alphaTPP, CTs, Mx, Mtip, Mat)	

independent variables: var_ind and var_pro

'V': flight speed V/V_{tip}

'Vh': horizontal speed V_h/V_{tip}

'mu', 'muHP': edgewise advance ratio μ (hub plane)

'muz', 'muzHP': axial velocity ratio μ_z (hub plane)

'alpha', 'alphaHP': shaft angle-of-attack $\alpha = \tan^{-1}(\mu_z/\mu)$ (hub plane)
'muTPP': edgewise advance ratio μ (tip-path plane)
'muzTPP': axial velocity ratio μ_z (tip-path plane)
'alphaTPP': shaft angle-of-attack $\alpha = \tan^{-1}(\mu_z/\mu)$ (tip-path plane)
'CTs', 'CT/s': blade loading C_T/σ
'Mx', 'offset': lift offset M_x/TR
'Mtip': tip Mach number $M_{\rm tip}$
'Mat': advancing tip Mach number M_{at}

MODEL_geTab: ground effect included in inflow, or table power evaluated at thrust decreased by κ_g, or table power decreased by f_g

MODEL_download≥ 2: table induced and profile power evaluated at thrust increased by $f_{DL} = 1/(1 - \Delta T/T)$

nonzero values of Ki and/or cdo in FltState supersede table (or table with equations) values

Chapter 49

Structure: DRotor

Variable	Type		Description	Default
		+	Rotor Drag, Standard Model	
		+	forward flight drag	
SET_Dhub	int	+	hub drag specification (1 fixed, D/q; 2 scaled, C_D; 3 scaled, squared-cubed; 4 scaled, square-root)	2
DoQ_hub	real	+	area $(D/q)_{\rm hub}$	
CD_hub	real	+	coefficient $C_{D\rm hub}$ (based on rotor area, $D/q = SC_D$)	0.0024
kDrag_hub	real	+	$k = (D/q)/(W/1000)^{2/3}$ or $(D/q)/W^{1/2}$ (Units_Dscale)	0.8
SET_Dpylon	int	+	pylon drag specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ_pylon	real	+	area $(D/q)_{\rm pylon}$	
CD_pylon	real	+	coefficient $C_{D\rm pylon}$ (based on pylon wetted area, $D/q = SC_D$)	0.
SET_Dduct	int	+	duct drag specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ_duct	real	+	area $(D/q)_{\rm duct}$	
CD_duct	real	+	coefficient $C_{D\rm duct}$ (based on duct wetted area, $D/q = SC_D$)	0.
SET_Dspin	int	+	spinner drag specification (1 fixed, D/q; 2 scaled, C_D)	1
DoQ_spin	real	+	area $(D/q)_{\rm spin}$	0.
CD_spin	real	+	coefficient $C_{D\rm spin}$ (based on spinner wetted area, $D/q = SC_D$)	0.
		+	vertical drag	
SET_Vhub	int	+	hub drag specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV_hub	real	+	area $(D/q)_{V\rm hub}$	
CDV_hub	real	+	coefficient $C_{DV\rm hub}$ (based on rotor area, $D/q = SC_D$)	0.
SET_Vpylon	int	+	pylon drag specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV_pylon	real	+	area $(D/q)_{V\rm pylon}$	
CDV_pylon	real	+	coefficient $C_{DV\rm pylon}$ (based on pylon wetted area, $D/q = SC_D$)	0.
SET_Vduct	int	+	duct drag specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV_duct	real	+	area $(D/q)_{V\rm duct}$	
CDV_duct	real	+	coefficient $C_{DV\rm duct}$ (based on duct wetted area, $D/q = SC_D$)	0.

		+	stopped/stowed rotor	
		+	forward flight hub drag	
DoQ_hubstop	real	+	area $(D/q)_{\text{hub-stop}}$	0.
CD_hubstop	real	+	coefficient $C_{D\text{hub-stop}}$ (based on rotor area, $D/q = SC_D$)	0.
DoQ_hubstow	real	+	area $(D/q)_{\text{hub-stow}}$	0.
CD_hubstow	real	+	coefficient $C_{D\text{hub-stow}}$ (based on rotor area, $D/q = SC_D$)	0.
		+	vertical hub drag	
DoQV_hubstop	real	+	area $(D/q)_{V\text{hub-stop}}$	0.
CDV_hubstop	real	+	coefficient $C_{DV\text{hub-stop}}$ (based on rotor area, $D/q = SC_D$)	0.
DoQV_hubstow	real	+	area $(D/q)_{V\text{hub-stow}}$	0.
CDV_hubstow	real	+	coefficient $C_{DV\text{hub-stow}}$ (based on rotor area, $D/q = SC_D$)	0.
		+	stopped blade drag	
CD_bladestop	real	+	coefficient $C_{D\text{blade}}$ (based on blade area, $D/q = SC_D$)	0.
		+	transition from forward flight drag to vertical drag	
MODEL_Dhub	int	+	hub drag model (0 none, 1 general, 2 quadratic)	2
MODEL_Dpylon	int	+	pylon drag model (0 none, 1 general, 2 quadratic)	2
MODEL_Dduct	int	+	duct drag model (0 none, 1 general, 2 quadratic)	2
X_hub	real	+	hub drag, transition exponent X_d	2.
X_pylon	real	+	pylon drag, transition exponent X_d	2.
X_duct	real	+	duct drag, transition exponent X_d	2.
Xh	real		hub drag, transition exponent X_d (derived)	
Xp	real		pylon drag, transition exponent X_d (derived)	
Xd	real		duct drag, transition exponent X_d (derived)	

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

component drag contributions must be consistent; pylon is rotor support, and nacelle is engine support
tiltrotor with tilting engines use pylon drag (and no nacelle drag), since pylon connected to rotor shaft axes
tiltrotor with nontilting engines: use nacelle drag as well
rotor with a spinner (such as on a tiltrotor aircraft) likely not have hub drag

SET_Dhub, hub drag: use one of DoQ_hub, CD_hub, kDrag_hub
units of kDrag are ft^2/klb$^{2/3}$ or m^2/Mg$^{2/3}$; ft^2/lb$^{1/2}$ or m^2/kg$^{1/2}$
CD = 0.0040 for typical hubs, 0.0024 for current low drag hubs, 0.0015 for faired hubs
kDrag (2/3 power) = 1.4 for typical hubs, 0.8 for current low drag hubs, 0.5 for faired hubs (English units)

kDrag (1/2 power) = 0.074 for single rotor helicopters, 0.049 for tandem helicopters,
0.038 for hingeless rotors, 0.027 for faired hubs (English units)
$W = f_W W_{MTO}$ (main rotor) or fThrust*Tdesign (antitorque or aux thrust rotor)

stopped/stowed rotor: areas or coefficients (based on SET_Dhub and SET_Vhub) replace hub drag

Chapter 50

Structure: IRotor

Variable	Type		Description	Default
		+	Rotor Interference, Standard Model	
		+	model	
MODEL_develop	int	+	development along wake axis (1 step function, 2 nominal, 3 input Xdevelop)	3
Xdevelop	real	+	rate parameter t	0.2
MODEL_boundary	int	+	immersion in wake (1 step function, 2 always immersed, 3 input Xboundary)	3
MODEL_contract	int	+	far wake contraction (0 no, 1 yes)	1
Xboundary	real	+	boundary transition s (fraction contracted radius)	0.2
MODEL_int_twin	int	+	twin rotor interference (1 no correction, 2 nominal, 3 input Ktwin)	1
Ktwin	real	+	velocity factor in overlap region K_T	1.4142
Nint_wing(nwingmax)	int	+	number wing span stations	6
Nint_tail(ntailmax)	int	+	number tail span stations	2
		+	interference factors $K_{\rm int}$ (0. for no interference)	
Kint_fus	real	+	at fuselage	1.0
Kint_wing(nwingmax)	real	+	at wing	1.0
Kint_tail(ntailmax)	real	+	at tail	1.0

Kint=0 to suppress interference at component; MODEL_int=0 for no interference at all
interference factor linearly transition from Kint at $V \leq$ Vint_low to 0 at $V \geq$ Vint_high

to account for wing or tail area in wake, interference averaged at Nint points along span

MODEL_develop: step function same as Xdevelop=0; nominal same as Xdevelop=1.
MODEL_boundary: step function same as Xboundary=0; always immersed same as Xboundary=∞
MODEL_twin: only for coaxial or tandem or side-by-side; nominal same as Ktwin=$\sqrt{2}$

		+	Induced power interference at wing	
KIND_int_wing	int	+	kind (1 wing-like, 2 propeller-like)	1
Cint_wing(nwingmax)	real	+	factor C_{int} (0. for no interference)	0.

For tiltrotors, typically the interference is wing-like, with $C_{\text{int}} \cong -0.06$

Chapter 51

Structure: WRotor

Variable	Type		Description	Default
		+	Rotor Group, NDARC Weight Model	
MODEL_config	int	+	model (1 rotor, 2 tail rotor, 3 auxiliary thrust)	1
MODEL_Wblade	int	+	blade weight model (1 AFDD82, 2 AFDD00, 3 lift offset, 4 Boeing, 5 GARTEUR, 6 Tishchenko, 7 generic)	1
MODEL_Whub	int	+	hub and hinge weight model (1 AFDD82, 2 AFDD00, 3 lift offset, 4 Boeing, 5 GARTEUR, 6 Tishchenko, 7 generic)	1
MODEL_Wshaft	int	+	inter-rotor shaft weight (0 none, 1 from lift offset, 2 from shaft length)	0
		+	AFDD00 weight models	
MODEL_type	int	+	hub weight equation depend on blade weight (for hub weight; 0 no, 1 yes)	1
KIND_rotor	int	+	rotor kind (for blade weight; 1 tilting, 2 not)	2
		+	AFDD00 and AFDD82: first flapwise natural frequency ν (per-rev at hover tip speed)	
flapfreq_blade	real	+	blade (0. to use flapfreq)	0.
flapfreq_hub	real	+	hub (0. to use flapfreq_blade)	0.
		+	lift offset rotor	
MODEL_offset	int	+	rotor tip clearance (for blade weight; 1 scaled, 2 fixed)	1
offset	real	+	design lift offset L (roll moment$/TR$)	0.3
thick20	real	+	blade airfoil thickness-to-chord ratio $\tau_{.2R}$ (at 20%R)	0.21
clearance_tip	real	+	tip clearance, scaled s/R or fixed s (ft or m)	0.05
thick25	real	+	Boeing: blade airfoil thickness-to-chord ratio $\tau_{.25R}$ (at 25%R)	0.15
rattach	real	+	Boeing (blade, hub, tail rotor, aux thrust): blade attachment (fraction rotor radius)	0.09
		+	generic blade	
Kblade	real	+	factor K_{blade}	0.
XbldN	real	+	exponent $X_{\text{bld}N}$	0.
XbldR	real	+	exponent $X_{\text{bld}R}$	0.
Xbldc	real	+	exponent $X_{\text{bld}c}$	0.
XbldV	real	+	exponent $X_{\text{bld}V}$	0.
Xbldf	real	+	exponent $X_{\text{bld}\nu}$	0.
XbldW	real	+	exponent $X_{\text{bld}W}$	0.

		+	generic hub	
Khub	real	+	factor $K_{\rm hub}$	0.
XhubN	real	+	exponent $X_{{\rm hub}N}$	0.
XhubR	real	+	exponent $X_{{\rm hub}R}$	0.
Xhubc	real	+	exponent $X_{{\rm hub}c}$	0.
XhubV	real	+	exponent $X_{{\rm hub}V}$	0.
Xhubf	real	+	exponent $X_{{\rm hub}\nu}$	0.
XhubW	real	+	exponent $X_{{\rm hub}W}$	0.
MODEL_tr	int	+	tail rotor weight model (1 AFDD, 2 Boeing, 3 GARTEUR)	1
thick70	real	+	GARTEUR: blade airfoil thickness-to-chord ratio $\tau_{.7R}$ (at 70%R)	0.11
MODEL_aux	int	+	auxiliary thrust weight model (1 AFDD10, 2 AFDD82, 3 Boeing, 4 GARTEUR, 5 Torenbeek, 6 generic)	1
thrust_aux	real	+	AFDD82: design maximum thrust T_{at}	0.
power_aux	real	+	AFDD10: design maximum power P_{at}	0.
material_aux	real	+	AFDD10: material factor f_m	1.
		+	generic propeller	
Kat	real	+	factor $K_{\rm at}$	0.
XatN	real	+	exponent $X_{{\rm at}N}$	0.
XatR	real	+	exponent $X_{{\rm at}R}$	0.
Xatc	real	+	exponent $X_{{\rm at}c}$	0.
XatV	real	+	exponent $X_{{\rm at}V}$	0.
XatP	real	+	exponent $X_{{\rm at}P}$	0.
fWfold	real	+	blade fold weight $f_{\rm fold}$ (fraction total blade weight)	0.
fWsupt	real	+	rotor support structure weight (fraction maximum takeoff weight)	0.
Usupt	real	+	rotor support weight per length $U_{\rm supt}$ (lb/ft or kg/m)	0.
fshaft	real	+	rotor shaft length (fraction rotor radius) $f_{\rm shaft}$	0.
Ushaft	real	+	rotor shaft weight per length $U_{\rm shaft}$ (lb/ft or kg/m)	0.
Uduct	real	+	duct weight per area $U_{\rm duct}$ (lb/ft^2 or kg/m^2)	1.5

MODEL_config: tail rotor and auxiliary thrust models use only rotor, support, and duct weights (not shaft, fold, or separate blade and hub weights)
duct weight only used for ducted fan configuration

for teetering and gimballed rotors, the flap frequency flapfreq_blade should be the coning frequency

The AFDD00 hub weight equation using the calculated blade weight (MODEL_type = 0) results in a lower average error, and best represents legacy rotor systems.
Using the actual actual blade weight (MODEL_type = 1) is best for advanced technology rotors with blades lighter than trend.

if thrust_aux$\neq 0$, supersedes design maximum thrust of rotor from sizing task
if power_aux$\neq 0$, supersedes design maximum power of rotor from sizing task
material_aux$=1$ for composite construction, 1.20 for wood, 1.31 for aluminum spar, 1.44 for aluminum construction
default Ω_{prop} is the reference rotor speed

typically fWfold = 0.04 for manual fold, 0.28 for automatic fold

rotor support structure weight must be consistent with engine support and pylon support weights of engine section

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		+	Custom Weight Model	
WtParam_rotor(8)	real	+	parameters	0.
			Weight Model Input	
			Blade	
nblade_b	int		number of blades	
radius_b	real		radius	
chord_b	real		blade mean chord	
taper_b	real		blade taper ratio	
Vtip_b	real		hover tip speed	
flapfreq_b	real		blade flap frequency	
HoD_b	real		coaxial separation h/D (for lift offset)	
SDGW_b	real		structural design gross weight (for lift offset)	
nz_b	real		design ultimate flight load factor at SDGW (for lift offset and Boeing)	
WMTO_b	real		maximum takeoff weight	
			Hub and hinge	
nblade_h	int		number of blades	
radius_h	real		radius	
chord_h	real		blade mean chord	
taper_h	real		blade taper ratio	

Vtip_h	real	hover tip speed
flapfreq_h	real	blade flap frequency
Wbld_h	real	blade weight
SDGW_h	real	structural design gross weight (for lift offset)
nz_h	real	design ultimate flight load factor at SDGW (for lift offset)
WMTO_h	real	maximum takeoff weight
		Shaft
radius_s	real	radius
chord_s	real	blade mean chord
taper_s	real	blade taper ratio
HoD_s	real	coaxial separation h/D (for lift offset)
SDGW_s	real	structural design gross weight (for lift offset)
nz_s	real	design ultimate flight load factor at SDGW (for lift offset)
		Fold
Wbld_f	real	blade weight
		Spinner
Dspin_n	real	spinner diameter (for Wspin)
		Support structure
WMTO_p	real	maximum takeoff weight
radius_p	real	radius
		Rotor/fan duct
Sduct_d	real	duct area
		Tail rotor
radius_t	real	radius
Qlimit_t	real	PSDlimit*R_mr/Vtip (for tail rotor)
		Auxiliary thrust
nblade_a	int	number of blades
radius_a	real	radius
chord_a	real	blade mean chord
Vtip_a	real	hover tip speed
RPMprop_a	real	propeller speed (rpm)
Taux_a	real	aux thrust Tdesign
Paux_a	real	aux power Pdesign

Chapter 52

Structure: Wing

Variable	Type		Description	Default
		+	Wing	
title	c*100	+	title	
notes	c*1000	+	notes	
kWing	int		wing number	
		+	Geometry	
wingload	real	+	wing loading $W/S = f_W W_D/S$	
fDGW	real	+	fraction DGW f_W (for wing loading)	1.0
area	real	+	area S	
span	real	+	span b	
chord	real	+	chord c	
AspectRatio	real	+	aspect ratio $\mathcal{R}$	

---

wing parameters: for each wing; input two quantities, other two derived (SizeParam input)
SET_wing = input two of ('area' or wing loading 'WL'), ('span' or 'ratio' or 'radius' or 'width' or 'hub' or 'panel'), 'chord', aspect ratio 'aspect'
SET_wing = 'ratio+XX' to calculate span from span of another wing
SET_wing = 'radius+XX' to calculate span from rotor radius
SET_wing = 'width+XX' to calculate span from rotor radius, fuselage width, and clearance (tiltrotor)
SET_wing = 'hub+XX' to calculate span from rotor hub position (tiltrotor)
SET_wing = 'panel+XX' to calculate span from wing panel widths
if wing sized from wing loading (SET_wing='WL+xx'), area = fDGW*DGW/wingload

rotor stopped as wing: identified by wing number Rotor%StopAsWing for stoppable rotor
use SET_wing='area+span', area = blade geometric area, span = $2R$, nPanel=1, zero weight
wing aerodynamic loads calculated when FltAircraft%STOP_rotor = stopped as wing

---

		+	Geometry	
		+	rotors	
nRotorOnWing	int	+	number of rotors mounted on wing	0
RotorOnWing(nrotormax)	int	+	rotor numbers	
		+	span calculation	
fSpan	real	+	ratio wing span to span of other wing, or to rotor radius	1.0
otherWing	int	+	other wing number	0
RotorForSpan	int	+	rotor number for span (if nRotorOnWing=0)	0
RotorOnPanel(npanelmax)	int	+	rotor at wing panel edge	
thick	real	+	thickness ratio τ_w	.23
fWidth_box	real	+	wing torque box chord w_{tb} (fraction wing chord)	0.45
SET_ac	int	+	aerodynamic center offset from pivot, at zero incidence (0 none, 1 fixed, 2 scale with chord)	0
dSLac	real	+	stationline	0.
dBLac	real	+	buttline	0.
dWLac	real	+	waterline	0.
SET_cg	int	+	center of gravity offset from pivot, at zero incidence (0 none, 1 fixed, 2 scale with chord)	0
dSLcg	real	+	stationline	0.
dWLcg	real	+	waterline	0.

RotorOnWing required for SET_wing = 'radius' or 'width' or 'hub'; MODEL_wing = tiltrotor; SET_Vdrag = airfoil c_{d90}
RotorOnPanel required for SET_panel = 'radius' or 'width' or 'hub'
SET_wing = 'radius' gets radius from RotorOnWing or RotorForSpan

taper, sweep, thickness used by weight equations
    taper and sweep calculated for entire wing from wing panel geometry
fWidth_box used by tiltrotor weight equations
thick and fWidth_box used for fuel in wing

		+	Geometry (for graphics)	
twist	real	+	twist	0.
			Geometry (derived)	
taper	real		taper ratio	

sweep	real		sweep (+ aft, deg)	
dihedral	real		dihedral (+ up, deg)	
MAC	real		mean aerodynamic chord $\bar{c}_A$	
xAC	real		mean aerodynamic center chordwise offset from root aero center $\bar{x}_A$ (+ aft)	
zAC	real		mean aerodynamic center vertical offset from root aero center $\bar{z}_A$ (+ up)	
StoppedRotor	int		stopped rotor number (0 not)	
		+	Geometry	
loc_wing	Location	+	aerodynamic center location	
nPanel	int	+	number of wing panels (maximum npanelmax)	1
KIND_ACoffset	int	+	aero center offset (1 fixed, 2 fraction root chord, 3 fraction inboard chord)	1
		+	Wing Panels	
SET_panel(npanelmax)	c*24	+	panel parameters	'span+taper'
span_panel(npanelmax)	real	+	span (one side), b_p	
area_panel(npanelmax)	real	+	area (both sides), S_p	
chord_panel(npanelmax)	real	+	mean chord, c_p	
fspan_panel(npanelmax)	real	+	ratio span to wing span (one side), $b_p/(b/2)$	1.
farea_panel(npanelmax)	real	+	ratio area to wing area (both sides), S_p/S	1.
fchord_panel(npanelmax)	real	+	ratio mean chord to wing chord, c_p/c	1.
		+	panel edges	
edge_panel(npanelmax)	real	+	outboard edge, y_E	
fedge_panel(npanelmax)	real	+	outboard edge, $\eta_E = y/(b/2)$	1.
lambdaI(npanelmax)	real	+	inboard chord ratio, c_I/c_{ref}	1.
lambdaO(npanelmax)	real	+	outboard chord ratio, c_O/c_{ref}	1.
		+	aerodynamic center locus	
sweep_panel(npanelmax)	real	+	sweep Λ_p (deg, + aft)	0.
dihedral_panel(npanelmax)	real	+	dihedral δ_p (deg, + up)	0.
dxAC_panel(npanelmax)	real	+	chordwise offset at panel inboard edge x_{Ip} (+ aft)	0.
dzAC_panel(npanelmax)	real	+	vertical offset at panel inboard edge z_{Ip} (+ up)	0.
		+	control surfaces	
fchord_flap(npanelmax)	real	+	flap chord $\ell_F = c_F/c_p$ (fraction panel chord)	0.25
fchord_flaperon(npanelmax)	real	+	flaperon/aileron chord $\ell_f = c_f/c_p$ (fraction panel chord)	0.25
fspan_flap(npanelmax)	real	+	flap span $f_b = b_F/b_p$ (fraction panel span)	0.5
fspan_flaperon(npanelmax)	real	+	flaperon/aileron span $f_b = b_f/b_p$ (fraction panel span)	0.5
fAC_aileron(npanelmax)	real	+	aileron aerodynamic center lateral position y	0.7

SET_wing, wing parameters: for each wing; input two quantities, other two derived
 SET_wing = input two of ('area' or wing loading 'WL'), ('span' or 'ratio' or 'radius' or 'width' or 'hub' or 'panel')
 SET_wing = 'chord', aspect ratio 'aspect'
 SET_wing = 'ratio+XX' to calculate span from span of another wing
 SET_wing = 'radius+XX' to calculate span from rotor radius
 SET_wing = 'width+XX' to calculate span from rotor radius, fuselage width, and clearance (tiltrotor)
 SET_wing = 'hub+XX' to calculate span from rotor hub position (tiltrotor)
 SET_wing = 'panel+XX' to calculate span from wing panel widths

wing panels: SET_panel not required with only one panel
SET_panel: specify consistent definition of panels (span, edge, area, chord)
 panel span: 'span' or 'bratio', else free
  'span' = input span_panel, b_p
  'bratio' = input ratio to wing span, fspan_panel, $b_p/(b/2)$
 panel outboard edge: 'edge', 'station', 'width', 'hub', or 'adjust' (not used for tip panel)
  'edge' = input edge_panel, y_E
  'station' = input fraction wing semispan fedge_panel, $\eta_E = y/(b/2)$
  'radius' = from rotor radius
  'width' = from rotor radius, fuselage width, and clearance (tiltrotor)
  'hub' = from rotor hub position (tiltrotor)
  'adjust' = from adjacent input panel span or span ratio
 panel area or chord: 'area', 'Sratio', 'chord', 'cratio', 'taper', else free
  'area' = input area_panel, S_p
  'Sratio' = input ratio to wing area, farea_panel, S_p/S
  'chord' = input chord_panel, c_p
  'cratio' = input ratio to wing chord, fchord_panel, c_p/c
  'taper' = from chord ratios lambdaI and lambdaO

 require consistent definition of panel spans and outboard edges, and consistent with SET_wing
  all edges known (from input edge or station, or from adjacent panel span or span ratio)
  resulting edges unique and sequential
  if wing span calculated from panel widths:
   one and only one input panel span or span ratio that not used to define edge
  if known span: no input panel span or span ratio that not used to define edge

usually best that any free span defined for inboard panel, not outboard panel
panel area or chord:
if one or more taper (and no free), calculate $c_{\rm ref}$ from wing area
if one (and only one) free, calculate S_p from wing area

fAC_aileron: from panel inboard edge, fraction panel span
for nPanel=1, from centerline and fraction wing semispan

Example input for typical wing geometry
Tiltrotor, one panel:
Size: SET_wing='WL+width', ! span from radius, fuselage width, and clearance; and wing loading
Rotor: SET_geom='tiltrotor',KIND_TRgeom=1, ! rotor lateral position (BL) from clearance
WingForRotor=1,otherRotor=1/2,
clearance_fus=x.,
fclearance_fus=1.,
Fuselage: Width_fus=x.,
Wing: wingload=x.,
nRotorOnWing=2,RotorOnWing=1,2,
nPanel=1,
SET_panel='span+taper',lambdaI=1.,lambdaO=1., ! not required with only one panel

Tiltrotor with wing extension, two panels
Size: SET_wing='WL+panel', ! span from wing panel widths; and wing loading
Rotor: SET_geom='tiltrotor',KIND_TRgeom=1, ! rotor lateral position (BL) from clearance
WingForRotor=1,otherRotor=1/2,PanelForRotor=1,
clearance_fus=x.,
fclearance_fus=1.,
Fuselage: Width_fus=x.,
Wing: wingload=x.,
nRotorOnWing=2,RotorOnWing=1,2,
nPanel=2,
SET_panel='width+taper','span+taper', ! outboard edge from R, Width_fus, and clearance; from span_panel
RotorOnPanel=1, 0,
span_panel=0., x.,
lambdaI=1., 1.,
lambdaO=1., x.,

sweep_panel=x., x.,
dihedral_panel=x., x.,
SET_ext=1,kPanel_ext=2,KIT_ext=0, ! wing extension

General wing, two panels, define chord and span of both
Size: SET_wing='panel+area', ! span from wing panel widths; and wing area
Rotor: SET_geom='standard',
Wing: area=x.,
nPanel=2,
SET_panel='span+chord','span+free', ! span from span_panel; chord from inboard chord_panel and area
span_panel=x., x.,
chord_panel=x., x.,

Tiltwing, three panels, four rotors
inboard hub at 1.75R (R + .25R clearance + .50R fuselage)
outboard hub at 3.6R (1.85R between hubs, overlap = .075)
wing tip at 4.2R (0.6R from outboard hub)
Size: SET_wing='WL+radius', ! calculate span from rotor radius; and wing loading
Rotor: right/right-inboard/left-inboard/left
SET_geom='tiltrotor',KIND_TRgeom=3, ! rotor lateral position (BL) from wing panel edge
WingForRotor=1,
positionOfRotor=1/1/-1/-1, ! right/left
PanelForRotor=2/1/1/2,
Wing: wingload=x.,
nRotorOnWing=4,RotorOnWing=1,2,3,4,
fSpan=4.2, ! fSpan = b/D
nPanel=3,
SET_panel='station+cratio','station+cratio','station+free',
fedge_panel=0.4167, 0.8571, 1., ! inboard-rotor/semispan, outboard-rotor/semispan, 1
fchord_panel=1., 1., 1.,

			Derived geometry	
iSET_panel_span(npanelmax)	int		span (SET_panel_span, bratio, free)	
iSET_panel_edge(npanelmax)	int		edge (SET_panel_edge, station, radius, width, hub, adjust)	
iSET_panel_area(npanelmax)	int		area (SET_panel_area, Sratio, chord, cratio, taper, free)	
kind_area	int		kind area and chord solution (1 tapered panels, 2 free panel)	
chordI(npanelmax)	real		inboard chord c_{Ip}	
chordO(npanelmax)	real		outboard chord c_{Op}	
eAC_aileron(npanelmax)	real		aileron aerodynamic center lateral position y (from centerline, fraction wing semispan)	
rArea_flap(npanelmax)	real		flap area/panel area	
rArea_flaperon(npanelmax)	real		flaperon-aileron area/panel area	
Ktef_flap(4,npanelmax)	real		trailing edge flap factors (L_f, X_f, M_f, D_f)	
Ktef_flaperon(4,npanelmax)	real		trailing edge flap factors (L_f, X_f, M_f, D_f)	
rArea_Wflap	real		total flap area/wing area	
rArea_Wflaperon	real		total flaperon-aileron area/wing area	
isConsistent	int		consistent geometry (0 if calculated geometry not consistent)	
		+	Wing Extensions	
SET_ext	int	+	extension (0 for none)	0
kPanel_ext	int	+	wing panel number	2
KIT_ext	int	+	wing extension as kit (0 not kit)	0
areaX	real		extension area S_X (both sides)	
spanX	real		extension span b_X (one side)	
areaI	real		inboard area $(S - S_X)$	
spanI	real		inboard span $(b - 2b_X)$	
area_flapI	real		inboard flap area	
area_flaperonI	real		inboard flaperon-aileron area	
AspectRatioI	real		inboard wing aspect ratio	
sweepI	real		inboard wing sweep	
taperI	real		inboard wing taper	
		+	Wing Kit	
KIT_wing	int	+	wing as kit (0 not, 1 kit, 2 kit as fixed useful load)	0
fWkit	real	+	kit weight (fraction total wing weight)	0.

		+	Controls (each panel)	
		+	kind deflection	
KIND_flap(npanelmax)	int	+	flap (1 fraction root flap; 2 increment relative root flap; 3 independent)	3
KIND_aileron(npanelmax)	int	+	aileron (1 fraction root aileron; 2 increment relative root aileron; 3 independent)	3
KIND_incid(npanelmax)	int	+	incidence (1 fraction root incidence; 2 increment relative root incidence; 3 independent)	3
KIND_flaperon(npanelmax)	int	+	kind flaperon deflection (1 fraction flap; 2 increment relative flap; 3 independent)	1
		+	flap δ_{Fp}	
INPUT_flap(npanelmax)	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_flap(ncontmax,nstatemax,npanelmax)	real	+	control matrix	
nVflap(npanelmax)	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
flap(nvelmax,npanelmax)	real	+	values	
Vflap(nvelmax,npanelmax)	real	+	speeds (CAS or TAS)	
		+	flaperon δ_{fp}	
INPUT_flaperon(npanelmax)	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_flaperon(ncontmax,nstatemax,npanelmax)	real	+	control matrix	
nVflaperon(npanelmax)	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
flaperon(nvelmax,npanelmax)	real	+	values	
Vflaperon(nvelmax,npanelmax)	real	+	speeds (CAS or TAS)	
		+	aileron δ_{ap}	
INPUT_aileron(npanelmax)	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_aileron(ncontmax,nstatemax,npanelmax)	real	+	control matrix	
nVaileron(npanelmax)	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
aileron(nvelmax,npanelmax)	real	+	values	
Vaileron(nvelmax,npanelmax)	real	+	speeds (CAS or TAS)	

		+	incidence i_p	
INPUT_incid(npanelmax)	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax,npanelmax)	real	+	control matrix	
nVincid(npanelmax)	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax,npanelmax)	real	+	values	
Vincid(nvelmax,npanelmax)	real	+	speeds (CAS or TAS)	
		+	flow control momentum coefficient C_μ	
INPUT_flow(npanelmax)	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_flow(ncontmax,nstatemax,npanelmax)	real	+	control matrix	
nVflow(npanelmax)	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
flow(nvelmax,npanelmax)	real	+	values	
Vflow(nvelmax,npanelmax)	real	+	speeds (CAS or TAS)	

---

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Trim Target	
		+	wing lift	
nVlift	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	
Klift(nvelmax)	real	+	target	
Vlift(nvelmax)	real	+	speeds (CAS or TAS)	

---

target definition determined by Aircraft%trim_quant
Klift can be fraction total aircraft lift, lift, or C_L

		+	Aerodynamics	
MODEL_aero	int	+	model (0 none, 1 standard)	1
Idrag	real	+	incidence angle i for helicopter nominal drag (deg; 0 for not tilt)	0.
AWing	AWing		standard model	
			Derived drag	
DoQC_wing	real		wing cruise drag, area $(D/q)_{\rm wing}$	
DoQH_wing	real		wing helicopter drag, area $(D/q)_{\rm wing}$	
DoQV_wing	real		wing vertical drag, area $(D/q)_{\rm wing}$	
DoQ_wb	real		wing-body interference drag, area $(D/q)_{wb}$	
Swet	real		total wetted area $S_{\rm wet}$	
prop_flow(3)	int		propulsion for flow control (group (1 engine, 2 jet), number, model)	
		+	Weight	
Weight	Weight		weight statement (component)	
		+	wing group	
MODEL_weight	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWprim	real	+	wing primary structure	0.
dWext	real	+	wing extension	0.
dWfair	real	+	fairing	0.
dWfit	real	+	fittings	0.
dWflap	real	+	flaps and control surfaces	0.
dWwfold	real	+	wing fold	0.
dWefold	real	+	wing extension fold	0.
WWing	WWing		NDARC model (except tiltrotor)	
WWingTR	WWingTR		NDARC tiltrotor model	
		+	tiltrotor model	
fWtip	real	+	factor for weight on wing tips	1.
xWtip	real	+	increment for weight on wing tips	0.
Wwing_total	real		wing weight	
Wwing_ext	real		wing extension weight	
Wwing_kit	real		wing kit weight	
Wtip_total	real		weight on wing tips	

		+	Technology Factors	
TECH_prim	real	+	wing primary structure (torque box) weight $\chi_{\rm prim}$	1.0
TECH_ext	real	+	wing extension weight $\chi_{\rm ext}$	1.0
TECH_fair	real	+	fairing weight $\chi_{\rm fair}$	1.0
TECH_fit	real	+	fittings weight $\chi_{\rm fit}$	1.0
TECH_flap	real	+	flaps and control surfaces weight $\chi_{\rm flap}$	1.0
TECH_wfold	real	+	wing fold weight $\chi_{\rm fold}$	1.0
TECH_efold	real	+	wing extension fold weight $\chi_{\rm efold}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

tiltrotor model requires weight on wing tips: both sides; calculated as sum of
rotor group, engine section or nacelle group, air induction group,
engine system, drive system (less drive shaft), rotary wing and conversion flight controls,
hydraulic group, trapped fluids, wing tip extensions
fWtip and xWtip adjust Wtip_total, without changing weight statements
negative increment required when engine and transmission not at tip location with rotor

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Chapter 53

Structure: AWing

Variable	Type		Description	Default
		+	Wing Aerodynamics, Standard Model	
AoA_zl	real	+	zero lift angle of attack α_{zl} (deg)	0.
CLmax	real	+	maximum lift coefficient $C_{L\max}$	1.5
SET_compress	int	+	compressibility correction (0 none, 1 lift, 2 drag, 3 both)	0
		+	lift	
SET_lift	int	+	specification (2 2D $dC_L/d\alpha$; 3 3D $dC_L/d\alpha$)	2
dCLda	real	+	lift curve slope $C_{L\alpha} = dC_L/d\alpha$ (per rad)	5.73
Tind	real	+	lift curve slope non-elliptical loading correction τ	0.25
Eind	real	+	Oswald or span efficiency e ($C_{Di} = (C_L - C_{L0})^2/(\pi e AR)$)	0.8
CL_Dmin	real	+	lift coefficient for minimum induced drag C_{L0}	0.
dCLda3D	real		incompressible 3D lift curve slope $C_{L\alpha}$ (derived)	
fDind	real		$1/(\pi e AR)$	
AoA_max	real		$\alpha_{\max} = C_{L\max}/(dC_L/d\alpha_{3D})$ (deg)	
Mdiv	real	+	lift-divergence Mach number M_{div}	0.75
		+	control (each wing panel)	
eta0(npanelmax)	real	+	lift effectiveness factor η_0, $\eta_0 - \eta_1\lvert\delta\rvert$	0.85
eta1(npanelmax)	real	+	lift effectiveness factor η_1, $\eta_0 - \eta_1\lvert\delta\rvert$	0.43
Kconl(npanelmax)	real	+	calibration or correction factor for lift K_ℓ	1.
Kconm(npanelmax)	real	+	calibration or correction factor for moment K_m	1.
Kcond(npanelmax)	real	+	calibration or correction factor for drag K_d	1.
Kconx(npanelmax)	real	+	calibration or correction factor for maximum lift K_x	1.
		+	pitch moment	
CMac	real	+	pitch moment coefficient about aerodynamic center C_{Mac}	0.
		+	Wing Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	

CD	real	+	coefficient C_{D0} (based on wing area, $D/q = SC_D$)	0.012
		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D; 3 airfoil c_{d90})	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient, C_{DV} (based on wing area, $D/q = SC_D$)	2.
cd90	real	+	airfoil drag coefficient c_{d90} (–90 deg)	1.4
fd90	real	+	airfoil drag coefficient flap effectiveness factor f_{d90}	2.5
CDcc	real	+	compressibility drag increment C_{Dcc} at M_{cc}	0.0011
Mcc0	real	+	critical Mach number constant M_{cc0}	0.74
Mcc1	real	+	critical Mach number constant M_{cc1}	0.31

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

		+	drag variation with angle of attack	
MODEL_drag	int	+	model (0 none, 1 general, 2 quadratic) $\Delta C_D = C_{D0} K_d |\alpha_e|^{X_d}$	2
AoA_Dmin	real	+	angle of attack for wing minimum drag $\alpha_{D\min}$ (deg)	0.
Kdrag	real	+	drag increment K_d	0.
Xdrag	real	+	drag increment X_d	2.
MODEL_sep	int	+	separated flow model (0 none, 1 general, 2 quadratic, 3 cubic) $\Delta C_D = C_{D0} K_s (|\alpha_e| - \alpha_s)^{X_s}$	3
AoA_sep	real	+	angle of attack for separation α_s (deg)	10.
Ksep	real	+	drag increment K_s	0.
Xsep	real	+	drag increment X_s	2.
Xd	real		drag exponent X_d (derived)	
Xs	real		drag exponent X_s (derived)	
		+	transition from forward flight drag to vertical drag	
AoA_tran	real	+	angle of attack for transition α_t (deg)	25.

Conventionally the Oswald efficiency e represents the wing parasite drag variation with lift, as well as the induced drag. If C_{Dp} varies with angle-of-attack, then e is just the span efficiency factor for the induced power (and C_{L0} should be zero).

		+	wing-body interference drag	
SET_wb	int	+	specification (1 fixed, D/q 2 scaled, C_D)	1
DoQ_wb	real	+	area $(D/q)_{wb}$	0.
CD_wb	real	+	coefficient C_{Dwb} (based on wing area, $D/q = SC_D$)	0.
		+	Interference velocity	
Etail(ntailmax)	real	+	angle of attack change at tail, $E = d\epsilon/d\alpha$ (rad/rad)	0.
Kint_wing(nwingmax)	real	+	interference factor $K_{\rm int}$ at other wings (0. for no interference)	0.
		+	interference power factor $K_{\rm int}$ at rotors (0. for no interference)	
Kintn_rotor(nrotormax)	real	+	normal (helicopter)	0.
Kintp_rotor(nrotormax)	real	+	inplane (propeller)	0.

---

for tandem wings, typically
Kint_wing(aftwing)=2. for front-on-aft interference
Kint_wing(frontwing)=0. for aft-on-front interference
for biplane wings, typically Kint_wing(otherwing)=0.7
with mutual interference (as for biplane), require trim or other iteration for convergence

interference power: inplane (propeller) factor Kintp_rotor negative for favorable

---

		+	Flow Control; $\Delta C_L = C_{L\alpha}(L_{\mu s}\sqrt{C_\mu} + L_{\mu 1}C_\mu + L_{\mu 2}C_\mu^2)$, $\Delta C_{L\max} = X_\mu C_\mu$, $\Delta C_M = M_\mu C_\mu$, $\Delta C_D = D_\mu C_\mu$	
MODEL_flow	int	+	model (0 none)	0
Lmus(npanelmax)	real	+	lift $L_{\mu s}$	1.4
Lmu1(npanelmax)	real	+	lift $L_{\mu 1}$	0.0
Lmu2(npanelmax)	real	+	lift $L_{\mu 2}$	0.0
Xmu(npanelmax)	real	+	maximum lift X_μ	1.0
Mmu(npanelmax)	real	+	moment M_μ	0.0
Dmu(npanelmax)	real	+	drag D_μ	0.0
Cmu_limit(npanelmax)	real	+	flow limit $C_{\mu\rm limit}$	1.0

Chapter 54

Structure: WWing

Variable	Type		Description	Default
		+	Wing Group, NDARC Weight Model	
MODEL_wing	int	+	model (1 area, 2 parametric, 3 tiltrotor, 4 other)	2
MODEL_other	int	+	model (1 Boeing, 2 GARTEUR, Torenbeek (3 light, 4 transport), Raymer (5 transport, 6 general aviation))	
fLift	real	+	lift factor	1.0
bFold	real	+	parametric method: fraction wing span that folds b_{fold} (0 to 1)	0.
wfus	real	+	Boeing: maximum fuselage width (fraction wing span)	
Vdive	real	+	Boeing or Raymer: design dive speed V_{dive} (knots)	200.
rflaplift	real	+	GARTEUR: ratio maximum lift with and without flaps	
		+	area method	
Uprim	real	+	weight per area U_{prim}, wing primary structure (lb/ft^2 or kg/m^2)	5.
Uext	real	+	weight per area U_{ext}, wing extension (lb/ft^2 or kg/m^2)	3.
		+	weight factors (fraction total wing weight)	
fWfair	real	+	fairing f_{fair}	0.10
fWfit	real	+	fittings f_{fit}	0.12
fWflap	real	+	flaps and control surfaces f_{flap}	0.10
fWfold	real	+	wing fold f_{fold}	0.
fWefold	real	+	wing extension fold f_{efold} (fraction wing extension weight)	0.
		+	Custom Weight Model	
WtParam_wing(8)	real	+	parameters	0.
			Weight Model Input	
Swing	real		wing area (without extension)	
Sext	real		wing extension area	
sweep	real		sweep angle	
AR	real		aspect ratio	
taper	real		taper ratio	
thick	real		thickness-to-chord ratio	

SDGW	real	structural design gross weight
nz	real	design ultimate flight load factor at SDGW
place_LG	int	landing gear placement (1 on body, 2 on wing)
SET_fold	int	folding

Chapter 55

Structure: WWingTR

Variable	Type		Description	Default
		+	Wing Group, NDARC Tiltrotor Weight Model	
		+	jump takeoff condition	
CTs_jump	real	+	rotor maximum blade loading C_T/σ	0.20
n_jump	real	+	load factor $n_{\rm jump}$ at SDGW	2.0
Vtip_jump	real	+	rotor tip speed (0. to use hover $V_{\rm tip}$)	750.0
thickTR	real	+	wing airfoil thickness-to-chord ratio τ_w	0.23
		+	width of wing structural attachments to body	
SET_Attach	int	+	definition (0 input wAttach, 1 fraction fuselage width, 2 fraction wing span)	1
fAttach	real	+	fraction width $w_{\rm attach}/w_{\rm fus}$	1.
wAttach	real	+	width $w_{\rm attach}$ (ft or m)	0.
fRG_pylon	real	+	pylon radius of gyration $r_{\rm pylon}/R$ (fraction rotor radius)	0.30
		+	wing mode frequencies (per rev, fraction rotor speed)	
freq_beam	real	+	beam bending frequency ω_B	0.5
freq_chord	real	+	chord bending frequency ω_C	0.8
freq_tors	real	+	torsion frequency ω_T	0.9
SET_refrpm	int	+	reference rotor speed (0 from input Vtip_freq, 1 hover $V_{\rm tip}$, 2 cruise $V_{\rm tip}$)	0
Vtip_freq	real	+	rotor tip speed	600.
MODEL_form	int	+	form factors (1 calculate, 2 input)	1
form_beam	real	+	torque box beam bending F_B	0.6048
form_chord	real	+	torque box chord bending F_C	0.4874
form_tors	real	+	torque box torsion F_T	1.6384
form_spar	real	+	spar caps vertical/horizontal bending F_{VH}	0.5018
eff_spar	real	+	spar structural efficiency e_{sp}	0.8
eff_box	real	+	torque box structural efficiency e_{tb}	0.8
		+	tapered spar cap correction factors	
C_t	real	+	weight correction C_t (equivalent stiffness)	0.75
C_j	real	+	weight correction C_j (equivalent strength)	0.50
C_m	real	+	strength correction C_m (equivalent stiffness)	1.5

		+	material (lb/in^2, in/in, lb/in^3; or N/m^2, m/m, kg/m^3)	
E_spar	real	+	spar modulus E_{sp}	10.E6
E_box	real	+	torque box modulus E_{tb}	10.E6
G_box	real	+	torque box shear modulus G_{tb}	4.0E6
StrainU_spar	real	+	spar ultimate strain allowable ϵ_U	0.01
StrainU_box	real	+	torque box ultimate strain allowable ϵ_U	0.01
density_spar	real	+	density spar cap ρ_{sp}	0.06
density_box	real	+	density torque box ρ_{tb}	0.06
		+	weight per area (lb/ft^2 or kg/m^2)	
Ufair	real	+	fairing $U_{\rm fair}$	2.
Uflap	real	+	flaps and control surfaces $U_{\rm flap}$	3.
UextTR	real	+	wing extension $U_{\rm ext}$	3.
		+	weight factor	
fWfitTR	real	+	fittings $f_{\rm fit}$ (fraction maximum thrust of one rotor)	0.01
fWfoldTR	real	+	wing fold $f_{\rm fold}$ (fraction total wing weight excluding fold)	0.
fWefoldTR	real	+	wing extension fold $f_{\rm efold}$ (fraction wing extension weight)	0.

jump takeoff: hover $V_{\rm tip}$ obtained from RotorOnWing(1) rotor

wing frequencies: reference rotor rotation speed from rotor $V_{\rm tip}$ and radius from RotorOnWing(1) rotor; hover tip speed Vtip_ref(1), cruise Vtip_cruise

thickTR only used for tiltrotor wing weight

SET_Attach: attachment width used for both torsion stiffness and fairing area

		+	Custom Weight Model	
WtParam_wingtr(8)	real	+	parameters	0.
			Weight Model Input	
span	real		wing span (without extension)	
chord	real		wing chord	
fWtb	real		width wing torque box (fraction chord)	

wfus	real	fuselage width
Sflap	real	area of control surfaces (flap and flaperon)
Sext	real	wing extension area
Wtip	real	weight on wing tips (both sides, except wing tip extension)
SDGW	real	structural design gross weight
radius	real	blade radius
Vtip_hover	real	hover tip speed
Vtip_cruise	real	cruise tip speed
Nrotor	int	number of rotors (for Tcap)
Ablade	real	blade area, one rotor (for Tcap)

Chapter 56

Structure: Tail

Variable	Type		Description	Default
		+	Empennage	
title	c*100	+	title	
notes	c*1000	+	notes	
KIND_tail	int	+	kind (1 horizontal tail, 2 vertical tail, 3 V-tail horizontal, 4 V-tail vertical)	1
isHortail	int		horizontal tail (0 vertical)	
isVtail	int		V-tail (0 not)	
kTail	int		tail number	
		+	Geometry	
SET_tail	c*16	+	specification	'vol+aspect'
area	real	+	area S	
span	real	+	span b	
chord	real	+	chord c	
AspectRatio	real	+	aspect ratio $\mathcal{R}$	
TailVol	real	+	tail volume V	
KIND_TailVol	int	+	tail volume reference (1 wing, 2 rotor)	2
TailVolRef	int	+	wing or rotor number for tail volume	1
otherVtail	int	+	other V-tail number	

KIND_tail used for geometry, baseline orientation, tail volume, tail weight model
tail parameters: input two quantities, others calculated
SET_tail = input two of ('area' or tail volume 'vol'), ('span' or aspect ratio 'aspect' or 'chord')
tail volume reference: tail volume $V = S\ell/RA$ (tailarea * taillength / (diskarea * radius))
or horizontal tail volume $V = S\ell/S_w c_w$ (tailarea * taillength / (wingarea * wingchord))
or vertical tail volume $V = S\ell/S_w b_w$ (tailarea * taillength / (wingarea * wingspan))
V-tail: modeled as pair of horizontal and vertical tails (identified by otherVtail)
separately sized, aerodynamic loads for each; dihedral calculated, cant set to zero
weight only for second tail, based on V-tail area and aspect ratio

		+	Geometry (for graphics and weights)	
taper	real	+	taper ratio	1.0
sweep	real	+	sweep (+ aft, deg)	0.
dihedral	real	+	dihedral (deg)	0.
thick	real	+	thickness ratio	.12
			Derived geometry	
iSet_tail_area	int		area (SET_tail_area, vol)	
iSet_tail_len	int		length (SET_tail_span, AR, chord)	
Length_tail	real		tail length ℓ	
rArea_control	real		control surface area/tail area	
Ktef_cont(4)	real		trailing edge flap factors (L_f, X_f, M_f, D_f)	
CBF(3,3)	real		tail axes relative airframe, C^{BF}	
areaVtail	real		V-tail area S_V	
spanVtail	real		V-tail span b_V	
AspectRatioVtail	real		V-tail aspect ratio	
		+	Geometry	
loc_tail	Location	+	aerodynamic center location	
cant	real	+	cant angle ϕ (deg)	0.
fchord_cont	real	+	control surface chord c_f/c (fraction tail chord)	0.25
fspan_cont	real	+	control surface span b_f/b (fraction tail span)	1.0
		+	Controls	
		+	elevator δ_e or rudder δ_r	
INPUT_cont	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_cont(ncontmax,nstatemax)	real	+	control matrix	
nVcont	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
cont(nvelmax)	real	+	values	
Vcont(nvelmax)	real	+	speeds (CAS or TAS)	
		+	incidence i	
INPUT_incid	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax)	real	+	control matrix	
nVincid	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax)	real	+	values	
Vincid(nvelmax)	real	+	speeds (CAS or TAS)	

---

horizontal tail cant angle: + to left (vertical tail for cant = 90)
vertical tail cant angle: + to right (horizontal tail for cant = 90)

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Aerodynamics	
MODEL_aero	int	+	model (0 none, 1 standard)	1
ATail	ATail		standard model	
			Derived drag	
DoQ_tail	real		tail drag, area $(D/q)_{\rm tail}$	
DoQV_tail	real		tail vertical drag, area $(D/q)_{V{\rm tail}}$	
Swet	real		total wetted area	
		+	Weight	
Weight	Weight		weight statement (component)	
		+	tail (empennage group)	
MODEL_weight	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWtail	real	+	basic	0.
dWfold	real	+	fold	0.
WTail	WTail		NDARC model	
Wtail_total	real		tail weight	
		+	Technology Factors	
TECH_tail	real	+	tail weight χ_{ht} or χ_{vt}	1.0
TECH_tfold	real	+	fold weight $\chi_{\rm fold}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

Chapter 57

Structure: ATail

Variable	Type		Description	Default
		+	Tail Aerodynamics, Standard Model	
AoA_zl	real	+	zero lift angle of attack α_{zl} (deg)	0.
CLmax	real	+	maximum lift coefficient $C_{L\max}$	1.
SET_compress	int	+	compressibility correction (0 none, 1 lift, 2 drag, 3 both)	0
		+	lift	
SET_lift	int	+	specification (2 2D $dC_L/d\alpha$; 3 3D $dC_L/d\alpha$)	2
dCLda	real	+	lift curve slope $C_{L\alpha} = dC_L/d\alpha$ (per rad)	5.73
Tind	real	+	lift curve slope non-elliptical loading correction τ	0.25
Eind	real	+	Oswald efficiency e ($C_{Di} = (C_L - C_{L0})^2/(\pi e AR)$)	0.8
CL_Dmin	real	+	lift coefficient for minimum induced drag C_{L0}	0.
dCLda3D	real		incompressible 3D lift curve slope $C_{L\alpha}$ (derived)	
fDind	real		$1/(\pi e AR)$	
AoA_max	real		$\alpha_{\max} = C_{L\max}/(dC_L/d\alpha_{3D})$ (deg)	
Mdiv	real	+	lift-divergence Mach number $M_{\rm div}$	0.75
		+	control	
eta0	real	+	lift effectiveness factor η_0, $\eta_0 - \eta_1\|\delta\|$	0.85
eta1	real	+	lift effectiveness factor η_1, $\eta_0 - \eta_1\|\delta\|$	0.43
Kconl	real	+	calibration or correction factor for lift K_ℓ	1.
Kconm	real	+	calibration or correction factor for moment K_m	1.
Kcond	real	+	calibration or correction factor for drag K_d	1.
Kconx	real	+	calibration or correction factor for maximum lift K_x	1.
		+	Tail Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	
CD	real	+	coefficient C_{D0} (based on tail area, $D/q = SC_D$)	0.011

		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient C_{DV} (based on tail area, $D/q = SC_D$)	1.
CDcc	real	+	compressibility drag increment C_{Dcc} at M_{cc}	0.0011
Mcc0	real	+	critical Mach number constant M_{cc0}	0.74
Mcc1	real	+	critical Mach number constant M_{cc1}	0.31

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

		+	drag variation with angle of attack	
MODEL_drag	int	+	model (0 none, 1 general, 2 quadratic) $\Delta C_D = C_{D0} K_d \lvert\alpha_e\rvert^{X_d}$	2
AoA_Dmin	real	+	angle of attack for tail minimum drag $\alpha_{D\min}$ (deg)	0.
Kdrag	real	+	drag increment K_d	0.
Xdrag	real	+	drag increment X_d	2.
Xd	real		exponent X_d (derived)	
		+	transition from forward flight drag to vertical drag	
AoA_tran	real	+	angle of attack for transition α_t (deg)	25.

Chapter 58

Structure: WTail

Variable	Type		Description	Default
		+	Tail, NDARC Weight Model	
MODEL_tail	int	+	model (1 horizontal tail, 2 vertical tail, 3 based on KIND_tail)	3
		+	horizontal tail	
MODEL_Htail	int	+	model (1 helicopter or compound, 2 tiltrotor or tiltwing, 3 area, 4 other)	1
MODEL_Hother	int	+	model (1 GARTEUR, Torenbeek (2 low speed, 3 transport), Raymer (4 transport, 5 general aviation))	
KIND_Htail	int	+	Torenbeek or Raymer: kind (1 fixed, 2 variable incidence)	1
wfus	real	+	Raymer: fuselage width at horizontal tail w_f/b_{ht} (fraction span)	0.2
		+	vertical tail	
MODEL_Vtail	int	+	model (1 helicopter or compound, 2 tiltrotor or tiltwing, 3 area, 4 other)	1
MODEL_Vother	int	+	model (1 GARTEUR, Torenbeek (2 low speed, 3 transport), Raymer (4 transport, 5 general aviation))	
place_AntiQ	int	+	AFDD: antitorque placement (0 none, 1 on tail boom, 2 on vertical tail)	1
KIND_Vtail	int	+	Torenbeek or Raymer: kind (1 conventional, 2 T-tail)	1
fTtail	real	+	Torenbeek: T-tail factor $(S_{ht}h_{ht})/(S_{vt}b_{vt})$	0.8
Vdive	real	+	design dive speed $V_{\rm dive}$ (knots)	200.
		+	area method	
Utail	real	+	weight per area $U_{\rm tail}$ (lb/ft^2 or kg/m^2)	3.
fTfold	real	+	fold weight factor $f_{\rm fold}$ (fraction total tail weight excluding fold)	0.

weight models can use taper ratio, sweep, and thickness ratio
dive speed: $V_{\rm max}$ = SLS max speed, Vdive $= 1.25V_{\rm max}$

Variable	Type		Description	Default
		+	Custom Weight Model	
WtParam_tail(8)	real	+	parameters	0.

		Weight Model Input
		Horizontal tail
area_ht	real	planform area
AR_ht	real	aspect ratio
		Vertical tail
area_vt	real	planform area
AR_vt	real	aspect ratio

Chapter 59

Structure: FuelTank

Variable	Type		Description	Default
		+	Fuel Tank System	
title	c*100	+	title	
notes	c*1000	+	notes	
kTank	int		tank number	
		+	Configuration	
SET_burn	int	+	fuel quantity stored and used (1 weight, 2 energy)	1
		+	fuel weight properties	
fuel_density	real	+	fuel weight per volume ρ_{fuel} (lb/gallon or kg/liter)	6.5
specific_energy	real	+	fuel energy per weight e_{fuel} (MJ/kg)	42.8
fFuelWing(nwingmax)	real	+	fraction wing torque box filled by fuel tanks	1.0
		+	fuel tank sizing	
Wfuel_cap	real	+	fuel capacity $W_{\text{fuel-cap}}$ (weight, lb or kg)	
Efuel_cap	real	+	fuel capacity $E_{\text{fuel-cap}}$ (energy, MJ)	
fFuel_cap	real	+	ratio capacity to mission fuel $f_{\text{fuel-cap}}$	1.0
dFuel_cap	real	+	capacity increment $d_{\text{fuel-cap}}$	0.
IDENT_battery	c*16	+	battery identification	' '

---

store and use weight: energy calculated from weight; capacity is usable fuel weight
use Wfuel_cap, Waux_cap, fuel_density, specific_energy, fFuelWing; fWtank, fWauxtank, other weight parameters
units of specific_energy = MJ/kg, regardless of Units_energy

store and use energy: fuel weight zero; capacity is usable fuel energy
use Efuel_cap, Eaux_cap, IDENT_battery; eWtank, eWauxtank, energy_density, other weight parameters
units of Efuel_cap, Eaux_cap = MJ, regardless of Units_energy

fuel tank sizing: usable fuel capacity Wfuel_cap (weight) or Efuel_cap (energy)
    SET_tank='input': input Wfuel_cap or Efuel_cap

SET_tank='miss': calculate from mission fuel used
Wfuel_cap or Efuel_cap = max(fFuel_cap*(maximum mission fuel), (maximum mission fuel)+(reserve fuel))
SET_tank='miss+power' = calculate from mission fuel used and mission battery discharge power
SET_tank='f(miss)' = function of mission fuel used
Wfuel_cap or Efuel_cap = dFuel_cap + fFuel_cap*((maximum mission fuel)+(reserve fuel))

battery identification: energy storage only, match ident of BatteryModel

		+	Geometry	
loc_tank	Location	+	location	
place	int	+	placement (for graphics; 1 internal, 2 sponson, 3 wing, 4 combination)	1
SET_length_wire	int	+	wiring length (1 input, 2 from component positions)	1
Length_wire	real	+	length ℓ_{wire}	
fLength_wire	real	+	factor	1.0
		+	Auxiliary Fuel Tank	
Mauxtanksize	int	+	number of auxiliary tank sizes (minimum 1, maximum nauxtankmax)	1
Waux_cap(nauxtankmax)	real	+	fuel capacity $W_{\text{aux}-\text{cap}}$ (weight)	1000.
Eaux_cap(nauxtankmax)	real	+	fuel capacity $E_{\text{aux}-\text{cap}}$ (energy)	20000.
fWauxtank(nauxtankmax)	real	+	tank weight f_{auxtank} (fraction auxiliary fuel weight)	0.
eWauxtank(nauxtankmax)	real	+	tank weight e_{auxtank} (MJ/kg or kWh/kg, Units_energy)	0.
DoQ_auxtank(nauxtankmax)	real	+	drag $(D/q)_{\text{auxtank}}$ (each tank)	
loc_auxtank(nauxtankmax)	Location	+	location	
		+	Equipment power	
MODEL_Peq	int	+	model (0 for none)	0
sfc	real	+	specific fuel consumption	0.
Peq_0	real	+	power loss $P_{\text{eq}0}$, constant	0.
Peq_d	real	+	power loss $P_{\text{eq}d}$, scale with density	0.
Peq_t	real	+	power loss $P_{\text{eq}t}$, scale with temperature	0.
KPeq_w	real	+	power loss $P_{\text{eq}w}$, weight factor	0.
XPeq_w	real	+	power loss $P_{\text{eq}w}$, weight exponent	0.
Peq_deice	real	+	deice power loss $P_{\text{eq}i}$	0.

specific fuel consumption: weight (lb/hp-hr or kg/kWh) or energy (hp/hp or kW/kW)

		+	Thermal management system	
SET_TMS	int	+	design rejected power $P_{\text{rej-design}}$ (0 none, 1 input, 2 fraction P_{cap})	0
Prej_design	real	+	power (hp or kW)	0.
fPrej_design	real	+	fraction	0.02
SET_FN	int	+	net jet force (0 for no force)	1
		+	Power distribution losses	
eta_dist	real	+	efficiency at P_{cap}	1.
		+	Cooling drag	
DoQ_cool	real	+	area $(D/q)_{\text{cool}}$	0.
			Derived	
Vfuel_cap	real		fuel capacity $V_{\text{fuel-cap}}$ (volume)	
Wfuel_wing	real		wing fuel capacity $W_{\text{fuel-wing}}$	
rWfuel_wing	real		wing fuel capacity (fraction Wfuel_cap)	
ncomp_in_tank	int		number of components in fuel tank system	
kBatteryModel	int		battery identification (BatteryModel, from IDENT_battery)	
specific_power	real		specific power $\pi_{\text{tank}} = x_{mbd} e_{\text{tank}}/(3.6(d_{\max} - d_{\min}))$ (kW/kg)	
fEfuel_act	real		actual battery capacity factor $1/(d_{\max} - d_{\min})$	
		+	Weight	
Weight	Weight		weight statement (component, not including auxiliary tanks)	
		+	fuel system (propulsion group)	
MODEL_weight	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWtank	real	+	tanks and support; battery management system	0.
dWplumb	real	+	plumbing; power distribution (wiring)	0.
WTank	WTank		NDARC model	
Neng	int		number of main engines	
fuelflow	real		total fuel flow F at DGW takeoff conditions (lb/hr or kg/hr)	
WTMS	real		battery thermal management system weight	

		+	Technology Factors	
TECH_tank	real	+	fuel tank weight χ_{tank}	1.0
TECH_plumb	real	+	plumbing weight χ_{plumb}	1.0

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

Chapter 60

Structure: WTank

Variable	Type		Description	Default
		+	Fuel System, NDARC Weight Model	
		+	weight storage	
		+	fuel tank	
MODEL_tank	int	+	model (1 fraction, 2 parametric, Torenbeek (3 integral, 4 generic), Raymer (5 transport, 6 general aviation))	2
ntank_int	int	+	number of internal tanks N_{int}	4
fWtank	real	+	tank weight f_{tank} (fraction fuel capacity weight)	0.09
Ktoler	real	+	parametric: ballistic tolerance factor f_{bt} (1.0 to 2.5)	2.5
KIND_crash	int	+	parametric: survivability (1 baseline, 2 UTTAS/AAH level of survivability)	2
Ktank	real	+	Torenbeek (generic): factor K_{tank}	3.2
Xtank	real	+	Torenbeek (generic): exponent X_{tank}	0.727
fint	real	+	Raymer: integral tank capacity (fraction total)	1.0
fprot	real	+	Raymer: protected tank capacity (fraction total)	1.0
		+	plumbing	
MODEL_plumb	int	+	model (1 fraction, 2 parametric)	2
nplumb	int	+	total number of fuel tanks (internal and auxiliary) for plumbing N_{plumb}	4
K0_plumb	real	+	weight increment $K_{0\mathrm{plumb}}$ (lb)	150.
K1_plumb	real	+	weight factor $K_{1\mathrm{plumb}}$ (lb)	2.0
fWplumb	real	+	plumbing weight f_{plumb} (fraction total fuel system weight)	0.4

MODEL_tank: fraction method uses fWtank; parametric method uses ntank_int, Ktoler, KIND_crash

K1_plumb is a crashworthiness and survivability factor; typically K1_plumb = 2.
K0_plumb is the sum of weights for auxiliary fuel, in-flight refueling, pressure refueling, inerting system, etc.; typically K0_plumb = 50 to 250 lb

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		+	energy storage	
eWtank	real	+	tank weight $e_{\rm tank}$ (MJ/kg or kWh/kg, Units_energy)	
energy_density	real	+	tank volume density $\rho_{\rm tank}$ (MJ/liter or kWh/liter, Units_energy)	
fBMS	real	+	battery management system (fraction basic tank weight)	0.2
		+	power distribution (wiring) weight	
Uwire	real	+	weight per length	0.62
fwire	real	+	fraction basic tank weight	0.2

specific energy $e_{\rm tank}$ and energy density $\rho_{\rm tank}$ based on usable fuel capacity (consistent with $d_{\max} - d_{\min}$)

		+	Custom Weight Model	
WtParam_tank(8)	real	+	parameters	0.
			Weight Model Input	
			Tanks and support	
Wint_t	real		internal fuel tank capacity (weight)	
Cint_t	real		internal fuel tank capacity (volume)	
			Plumbing	
Neng_p	int		number of main engines	
fuelflow_p	real		fuel flow rate	
Xtank_p	real		tank weight	
			Energy tank	
Eint_e	real		internal fuel tank capacity (energy)	
xwire_e	real		wiring length	
Pcap_e	real		battery power capacity	

Chapter 61

Structure: Propulsion

Variable	Type		Description	Default
		+	Propulsion Group	
title	c*100	+	title	
notes	c*1000	+	notes	

propulsion group is set of components and engine groups, connected by drive system
components (rotors) define power required, engine groups define power available
drive system defines ratio of rotational speeds of components (relative primary rotor speed)

Variable	Type		Description	Default
kPropulsion	int		propulsion group number	
			Specification	
kRotor_prim	int		primary rotor	
rotor_in_group(nrotormax)	int		rotors in group (0 no, 1 main rotor, 2 other)	
nRotor	int		number of rotors in group	
nRotor_main	int		number of main rotors	
kEngine_prim	int		primary engine group	
engine_in_group(nengmax)	int		engine groups in propulsion group (0 no, 1 only produce power, 2 can consume power)	
nEngineGroup	int		number of engine groups	
firstEngineGroup	int		first engine group	
canConsumePower	int		engine group generator or compressor, can consume shaft power (0 only produce power)	
		+	Drive system	
nGear	int	+	number of states (maximum ngearmax)	1
STATE_gear_var	int	+	drive system state for variable speed transmisson (0 for none)	0

drive system branches: one primary rotor per propulsion group (specify $V_{\rm tip}$), others dependent (specify gear ratio)
specify primary engine group only if no rotors in propulsion group
drive system state: identifies gear ratio set for multiple speed transmissions
state=0 to use conversion schedule, state=n (1 to nGear) to use gear ratio #n
variable speed transmission: for drive system state STATE_gear_var, gear ratio factor $f_{\rm gear}$ (control) included
when evaluate rotational speed of dependent rotors and engines

		+	Transmission losses	
MODEL_Xloss	int	+	model (1 fraction component power required; 2 with function drive shaft limit)	2
fPloss_xmsn	real	+	gear box loss $\ell_{\rm xmsn}$ (fraction total component power required)	0.04
Ploss_windage	real	+	power loss due to windage $P_{\rm windage}$	0.
		+	Accessory losses	
Pacc_0	real	+	power loss $P_{\rm acc0}$, constant	0.
Pacc_d	real	+	power loss $P_{{\rm acc}d}$, scale with density	0.
Pacc_n	real	+	power loss $P_{{\rm acc}n}$, scale with density and rpm	0.
Pacc_deice	real	+	deice power loss $P_{{\rm acc}i}$	0.
fPacc_ECU	real	+	ECU (etc.) power loss $\ell_{\rm acc}$ (fraction component+transmission power)	0.
fPacc_IRfan	real	+	IRS fan loss $\ell_{\rm IRfan}$ (fraction total engine power)	0.
		+	Geometry	
SET_length	int	+	drive shaft length (1 input, 2 from hub positions, 3 scale with radius)	2
Length_ds	real	+	length ℓ_{DS}	
fLength_ds	real	+	factor	0.9

SET_length: input (use Length_ds) or calculated (from fLength_ds)

		+	Drive system torque limit	
Plimit_ds	real	+	drive system power limit $P_{DS{\rm limit}}$	
fPlimit_ds	real	+	drive system power limit factor	1.0
SET_Plimit_size	int	+	drive system limit when sizing transmission (0 not applied to power available)	0

		+	Drive system ratings	
nrate_ds	int	+	number of ratings (maximum nratemax)	1
rating_ds(nratemax)	c*12	+	drive system rating designation	' '
frating_ds(nratemax)	real	+	torque limit factor	1.0
		+	schedule	
Vdrive_hover	real	+	maximum speed for hover and helicopter mode (CAS or TAS)	
Vdrive_cruise	real	+	minimum speed for cruise (CAS or TAS)	
rating_ds_hover	c*12	+	rating for hover and helicopter mode ($V \leq V_{\text{drive-hover}}$)	' '
rating_ds_conv	c*12	+	rating for conversion mode ($V_{\text{drive-hover}} < V < V_{\text{drive-cruise}}$)	' '
rating_ds_cruise	c*12	+	rating for cruise mode ($V \geq V_{\text{drive-cruise}}$)	' '
			Derived drive system limit	
Qlimit_ds	real		drive system torque limit ($P_{DS\text{limit}}$ at primary rotor reference speed)	
arating_ds(nratemax)	c*12		drive system rating designation	
xrating_ds(nratemax)	real		torque limit factor	
krate_ds_hover	int		rating number for hover and helicopter mode	
krate_ds_conv	int		rating number for conversion mode	
krate_ds_cruise	int		rating number for cruise mode	

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drive system torque limits: SET_limit_ds = input (use Plimit_xx) or calculate (from fPlimit_xx)
SET_limit_ds='input': Plimit_ds input
SET_limit_ds='ratio': from takeoff power, fPlimit_ds$\sum(N_{\text{eng}} P_{\text{eng}})$
SET_limit_ds='Pav': from engine power available at transmission sizing conditions and missions (DESIGN_xmsn)
fPlimit_ds$(\Omega_{\text{ref}}/\Omega_{\text{prim}}) \sum(N_{\text{eng}} P_{av})$
SET_limit_ds='Preq': from engine power required at transmission sizing conditions and missions (DESIGN_xmsn)
fPlimit_ds$(\Omega_{\text{ref}}/\Omega_{\text{prim}}) \sum(N_{\text{eng}} P_{req})$
engine shaft: options for SET_limit_ds≠'input'
SET_limit_es=0: Plimit_es
SET_limit_es=1: fPlimit_es × (engine group P_{eng} or P_{av} or P_{req}, depending on SET_limit_ds)
SET_limit_es=2: fPlimit_es $\times P_{DS\text{limit}}(P_{\text{eng}EG}/P_{\text{eng}PG})$

drive system power limit: corresponds to power of all engines of propulsion group (all engine groups)
can be used for trim (trim_quant='Q margin')
used for drive system weight, tail rotor weight, transmission losses
limits propulsion group P_{av} (if FltState%SET_Plimit=on)

engine shaft power limit: corresponds to all engines of engine group (nEngine $\times$ Peng)
limits engine group P_{av} (if FltState%SET_Plimit=on)
rotor shaft power limit: corresponds to one rotor
all limits
can be used for max effort in flight state (max_quant='Q margin')
can be used for max gross weight in flight condition or mission (SET_GW='maxQ' or 'maxPQ')
always check and print whether exceed torque limit

the engine model gives the power available, accounting for installation losses and mechanical limits
then the power available is reduced by the factor FltState%fPower
next torque limits are applied (unless FltState%SET_Plimit=off), first engine shaft limit and then drive system limit

SET_Plimit_size=0: drive system limits are not applied for transmission sizing conditions and mission segments (DESIGN_xmsn); otherwise use FltState%SET_Plimit

drive system ratings: blank to use engine ratings of first engine group
limit at flight state is $rxf_Q P_{\rm limit}$, where r is the rotor speed ratio and x is the rating factor frating_ds
if nrate_ds≤ 1, drive system rating not used
schedule used if FltAircraft%rating_ds='speed'

		+	Control	
		+	rotational speed increment ΔN, primary rotor or primary engine (rpm)	
INPUT_DN	int	+	connection to aircraft controls (0 none, 1 input T matrix)	0
T_DN(ncontmax,nstatemax)	real	+	control matrix	
nVDN	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
DN(nvelmax)	real	+	values	
VDN(nvelmax)	real	+	speeds (CAS or TAS)	

---

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Weight	
Weight	Weight		weight statement (component, not including EngineGroup)	
		+	drive system (propulsion group)	
MODEL_DS	int	+	model (0 input, 1 NDARC, 2 custom)	1
		+	weight increment	
dWgb	real	+	gear box	0.
dWrs	real	+	rotor shaft	0.
dWds	real	+	drive shaft	0.
dWrb	real	+	rotor brake	0.
dWcl	real	+	clutch	0.
dWgd	real	+	gas drive	0.
WDrive	WDrive		NDARC model	
STATE_gear_wt	int	+	drive system state for weight	1
kEngineGroup_wt(2)	int	+	EngineGroup for weight (input, output)	1
Wtip	real		weight on wing tip	
Wgbrs	real		weight gear box and rotor shaft	
		+	Technology Factors	
TECH_gb	real	+	gear box weight χ_{gb}	1.0
TECH_rs	real	+	rotor shaft weight χ_{rs}	1.0
TECH_ds	real	+	drive shaft weight χ_{ds}	1.0
TECH_rb	real	+	rotor brake weight χ_{rb}	1.0
TECH_cl	real	+	clutch weight χ_{cl}	1.0
TECH_gd	real	+	gas drive weight χ_{gd}	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

kEngineGroup_wt: always identify engine group for drive system input
if propulsion group has rotors, primary rotor speed used for drive system output
if propulsion group does not have rotors, must identify engine group for drive system output

drive system weight = gear box (including rotor shaft) + drive shaft + rotor brake + clutch + gas drive
tiltrotor wing weight model requires weight on wing tip (drive system, without rotor shaft)

Chapter 62

Structure: WDrive

Variable	Type		Description	Default
		+	Drive System, NDARC Weight Model	
		+	gear box (including rotor shafts)	
MODEL_gbrs	int	+	model (1 AFDD83, 2 AFDD00, 3 other)	1
MODEL_other	int	+	model (1 Boeing, 2 Boeing (alternate), GARTEUR (3 helicopter, 4 tiltrotor), 5 Tishchenko, 6 generic)	
fShaft	real	+	rotor shaft weight f_{rs} (fraction gear box and rotor shaft weight)	0.13
ngearbox	int	+	AFDD83: number of gear boxes N_{gb}	7
fTorque	real	+	AFDD83: second (main or tail) rotor rated torque f_Q (fraction total drive system rated torque)	0.03
nstage	int	+	Boeing: number of stages in main-rotor drive	4
		+	generic gearbox	
Kgbrs	real	+	factor K_{gbrs}	0.
XgbP	real	+	exponent X_{gbP}	0.
Xgbe	real	+	exponent X_{gbe}	0.
Xgbr	real	+	exponent X_{gbr}	0.
KIND_other	int	+	other: separate tail rotor drive weight increment (0 none)	0
Ktrgb	real	+	tail rotor drive weight increment factor K_{trgb}	1.0
fPower_tr	real	+	tail rotor power (fraction total drive system rated power)	0.15
gear_tr	real	+	tail rotor gear ratio	5.0
		+	drive shaft and rotor brake	
MODEL_dsrb	int	+	model (0 none, 1 AFDD82)	1
ndriveshaft	int	+	AFDD82: number of intermediate drive shafts N_{ds} (excluding rotor shafts)	6
fPower	real	+	AFDD82: second (main or tail) rotor rated power f_P (fraction total drive system rated power)	0.15

fPower = fTorque*(otherrotor RPM)/(mainrotor RPM)
typically fTorque=fPower=0.6 for twin main rotors (tandem, coaxial, tiltrotor)
for single main rotor and tail rotor, fTorque = 0.03, fPower = 0.15 (0.18 for 2-bladed teeter)

typically fShaft = 0.13 (data range 0.06 to 0.20)

		+	Custom Weight Model	
WtParam_drive(8)	real	+	parameters	0.
			Weight Model Input	
			Gear box and rotor shaft	
PDSlimit_gb	real		drive system rated power	
RPMrotor_gb	real		rotor speed (rpm)	
RPMeng_gb	real		engine speed (rpm)	
Nrotor_gb	int		number of main rotors	
			Drive shaft	
PDSlimit_ds	real		drive system rated power	
RPMrotor_ds	real		rotor speed (rpm)	
xhub_ds	real		length of drive shaft between rotors	
			Rotor brake	
Wblade_rb	real		blade weight (all blades, all rotors)	
Vtip_rb	real		main rotor tip speed	

Chapter 63

Structure: EngineGroup

Variable	Type		Description	Default
		+	Engine Group	
title	c*100	+	title	
notes	c*1000	+	notes	
kEngineGroup	int		engine group number	
		+	Description	
MODEL_engine	c*32	+	engine model	'RPTEM'
IDENT_engine	c*16	+	engine identification	'Engine'
IDENT_system2	c*16	+	second system identification	' '
nEngine	int	+	number of engines N_{eng}	1
nEngine_main	int	+	number of main engines	1
Peng	real	+	engine power P_{eng} (SLS static at takeoff rating, $0.$ for P0_ref(rating_to))	0.
rating_to	c*12	+	takeoff power rating	'MCP'
rating_idle	c*12	+	idle power rating	'MCP'
kFuelTank	int	+	fuel tank system number	1
kRotor_react	int	+	rotor number for reaction drive	
fuselage_flow	int	+	fuselage flow control (0 not)	1
wing_flow(nwingmax)	int	+	wing flow control (0 not)	1
		+	Propulsion Group	
kPropulsion	int	+	group number	1
KIND_xmsn	int	+	drive system branch (1 primary, 0 dependent)	0
INPUT_gear	int	+	gear ratio input (1 from Nspec, 2 gear)	1
gear(ngearmax)	real	+	engine gear ratio $r = \Omega_{\text{spec}}/\Omega_{\text{prim}}$ (ratio rpm to rpm of primary rotor in propulsion group)	1.0
			Derived	
iMODEL_engine	int		engine model (MODEL_engine_xxx)	
KIND_engine	int		engine model (MODEL_engine_RPTEM, table, recip, comp, motor)	
canConsumePower	int		can consume shaft power (0 only produce power), generator or compressor	
canProducePower	int		can produce shaft power (0 only consume power)	

isConvertReact	int	convertible engine, reaction drive (0 not)
isConvertJet	int	convertible engine, turbojet/fan (0 not)
kModel_eng	int	identification (EngineModel or EngineTable or RecipModel or CompressorModel or MotorModel, from IDENT_engine)
kModel_sys2	int	identification (EngineModel, from IDENT_system2)
kBattery	int	battery model, from kFuelTank (0 for none)
nrate	int	number of ratings
rating(nratemax)	c*12	rating designations (lowercase)
krateC	int	MCP rating number
krate_to	int	takeoff power rating number
WOneEng	real	weight one engine $W_{\text{one eng}}$
Nref	real	reference engine speed (at drive state #1)
comp_flow	int	flow control, any component (0 none)

MODEL_engine: engine model
- 'RPTEM', 'shaft' = turboshaft engine (RPTEM); IDENT_engine → EngineModel; fuel is weight
- 'table' = turboshaft engine (table); IDENT_engine → EngineTable; fuel is weight
- 'recip' = reciprocating engine; IDENT_engine → RecipModel; fuel is weight
- 'comp' = compressor; IDENT_engine → CompressorModel; not use fuel
- 'comp+react' = compressor for reaction drive; IDENT_engine → CompressorModel; not use fuel
- 'comp+flow' = compressor for flow control; IDENT_engine → CompressorModel; not use fuel
- 'motor' = electric motor; IDENT_engine → MotorModel; fuel is energy
- 'gen' = electric generator; IDENT_engine → MotorModel; fuel is energy (generated, not burned)
- 'motor+gen' = motor + generator (mode $B \geq 0$ for motor); IDENT_engine → MotorModel; fuel is energy

MODEL_engine: convertible engine; only with turboshaft
- '+react' = reaction drive (mode $B = 1$); IDENT_system2 → EngineModel
- '+jet', '+fan' = turbojet/turbofan (mode $B = 1$); IDENT_system2 → EngineModel

engine identification: match ident of EngineModel or EngineTable or RecipModel or CompressorModel or MotorModel
second system identification: match ident of EngineModel; not use weight
number of main engines: for fuel tank weight

for fixed engine: use $P_{\text{eng}} = 0.$ and no size task (or engine power not sized)
takeoff power rating: for engine scaling, aircraft power loading, fuel tank weight
FltState%rating can be set to 'idle' (rating_idle) or 'takeoff' (rating_to)

fuel tank system identified for burn must store and use weight (turboshaft, reciprocating)
or energy (motor, may have BatteryModel)
fuel tank system identified for generation must store and use energy (may have BatteryModel)

drive system branch: primary engine group only designated if no rotors for propulsion group
INPUT_gear: calculate gear from Nspec and Vtip_ref of primary rotor of propulsion group, or specify gear ratio
variable speed transmission: for drive system state STATE_gear_var, gear ratio factor f_{gear} (control) included
when evaluate rotational speed of engine

		+	Sizing	
SET_power	int	+	specification (0 sized, 1 fixed)	0
fPsize	real	+	sized power ratio f_n	1.0
SET_Pother	int	+	sized power from other engine group (0 not)	0
fEsize(nengmax)	real	+	fraction other engine group power f_E	0.

SET_power: if SIZE_perf='engine', used to distribute propulsion group power required among engine groups
$P_{\text{eng}} = f_n P_{\text{sized}}/N_{\text{eng}}$ for n-th engine group, $P_{\text{sized}} = P_{PG} - \sum_{\text{fixed}} N_{\text{eng}} P_{\text{eng}}$
must size at least first engine group, so SET_power and fPsize values not used for first group
fPsize calculated for first engine group, must be > 0.
not used (SET_power=1) if group consumes power (compressor or generator, which sized if SIZE_engine='engine')
FltState%SET_Preq specifies distribution of power required for flight state

SET_Pother: size power from engine group of other propulsion groups, $\max(P_{\text{eng}}, f_E P_{\text{eng-other}})$

		Engine model performance parameters (one engine)
P0(nratemax)	real	power (P_0)
SP0(nratemax)	real	specific power (SP_0)
Pmech(nratemax)	real	mechanical limit of power (P_{mech} or P_{peak})
sfc0C	real	specific fuel consumption at MCP (sfc_{0C})
Fg0C	real	gross jet thrust at MCP ($F_{g0C} = SF_{0C}\dot{m}_{0C}$)

Nspec	real		specification engine speed ($N_{\rm spec}$)	
Nopt0C	real		optimum engine speed at MCP ($N_{{\rm opt}0C}$)	
mdot0C	real		mass flow at MCP ($\dot{m}_{0C} = P_{0C}/SP_{0C}$)	
wdot0C	real		fuel flow at MCP ($\dot{w}_{0C} = {\rm sfc}_{0C} P_{0C}$)	
sfc0(nratemax)	real		specific fuel consumption (${\rm sfc}_0$)	
			Engine model performance parameters (one engine), ratio converted to base	
rsfc0C_conv	real		specific fuel consumption at MCP	
rFg0C_conv	real		gross jet thrust at MCP, jet/fan only	
rwdot0C_conv	real		fuel flow at MCP	

---

reciprocating: only P0, Pmech, Nspec used, and sfc0
motor or generator: only P0, Pmech, Nspec used

		+	Drive system torque limit	
SET_limit_es	int	+	engine shaft (0 input, 1 fraction power, 2 fraction drive system limit)	1
Plimit_es	real	+	engine shaft power limit $P_{ES{\rm limit}}$	
fPlimit_es	real	+	engine shaft power limit factor	1.0
			Derived engine shaft limit	
Qlimit_es	real		engine shaft torque limit ($P_{ES{\rm limit}}$ at engine reference speed)	

---

drive system torque limits: SET_limit_ds = input (use Plimit_es) or calculated (from fPlimit_es)
- SET_limit_ds='input': Plimit_ds input
- SET_limit_ds='ratio': from takeoff power, fPlimit_ds$\sum(N_{\rm eng} P_{\rm eng})$
- SET_limit_ds='Pav': from engine power available at transmission sizing conditions and missions (DESIGN_xmsn)
  - fPlimit_ds$(\Omega_{\rm ref}/\Omega_{\rm prim}) \sum(N_{\rm eng} P_{av})$
- SET_limit_ds='Preq': from engine power required at transmission sizing conditions and missions (DESIGN_xmsn)
  - fPlimit_ds$(\Omega_{\rm ref}/\Omega_{\rm prim}) \sum(N_{\rm eng} P_{req})$

engine shaft: options for SET_limit_ds≠'input'
- SET_limit_es=0: Plimit_es
- SET_limit_es=1: fPlimit_es × (engine group $P_{\rm eng}$ or P_{av} or P_{req}, depending on SET_limit_ds)
- SET_limit_es=2: fPlimit_es $\times P_{DS{\rm limit}}(P_{{\rm eng}EG}/P_{{\rm eng}PG})$

engine shaft power limit: corresponds to all engines of engine group (nEngine × Peng)
limits engine group P_{av} (if FltState%SET_Plimit=on)
can be used for max effort in flight state (max_quant='Q margin')
can be used for max gross weight in flight condition or mission (SET_GW='maxQ' or 'maxPQ')
always check and print whether exceed torque limit

		+	Installation	
Kffd	real	+	deterioration factor on engine fuel flow or performance K_{ffd}	1.05
eta_d	real	+	engine inlet efficiency η_d (fraction, for δ_M)	0.98
		+	power losses (fraction power available, P_{loss}/P_a)	
fPloss_inlet	real	+	engine inlet loss ℓ_{in}	0.
fPloss_ps	real	+	inlet particle separator loss ℓ_{in}	0.
fPloss_exh	real	+	engine exhaust loss ℓ_{ex} (IRS off)	0.015
		+	auxiliary air momentum drag (IRS off)	
fMF_auxair	real	+	mass flow f_{aux} (fraction engine mass flow)	0.007
eta_auxair	real	+	ram recovery efficiency η_{aux}	0.75
		+	IR suppressor	
		+	power losses (IRS on)	
fPloss_exh_IRon	real	+	engine exhaust loss ℓ_{ex}	0.030
		+	auxiliary air momentum drag (IRS on)	
fMF_auxair_IRon	real	+	mass flow f_{aux} (fraction engine mass flow)	0.01
eta_auxair_IRon	real	+	ram recovery efficiency η_{aux}	0.75
		+	Convertible	
Kffd_conv	real	+	deterioration factor on engine fuel flow or performance K_{ffd}	1.05
		+	power losses (fraction power available, P_{loss}/P_a)	
fPloss_exh_conv	real	+	engine exhaust loss ℓ_{ex}	0.015
		+	Thermal management system	
SET_TMS	int	+	design rejected power $P_{\text{rej-design}}$ for one engine (0 none, 1 input, 2 fraction P_{eng})	0
Prej_design	real	+	power (hp or kW)	0.
fPrej_design	real	+	fraction	0.02
		+	Model	
SET_FN	int	+	net jet force (0 for no force)	1
SET_Daux	int	+	auxiliary air momentum drag (0 for no drag)	1

installation power losses = inlet + particle separator + exhaust (including IRS)
IR suppressor state specified by STATE_IRS in operating condition
motor or generator: only use Kffd, thermal management system

		+	Geometry	
loc_engine	Location	+	location	
direction	c*16	+	nominal orientation ('+x', '–x', '+y', '–y', '+z', '–z')	'x'
SET_geom	int	+	position (0 standard, 1 tiltrotor, 2 rotor)	0
RotorForEngine	int	+	rotor number	1
SET_Swet	int	+	nacelle/cowling wetted area (1 fixed, input Swet; 2 scaled, W_{ES}; 3 scaled, W_{ES} and W_{gbrs})	2
Swet	real	+	area $S_{\rm wet}$ (per engine)	0.
kSwet	real	+	factor, $k = S_{\rm wet}/(w/N_{\rm eng})^{2/3}$ (Units_Dscale)	0.8
Snac	real		nacelle/cowling area $S_{\rm nac}$	
Swet_nac	real		total wetted area	

SET_geom: calculation override part of location input
SET_geom=tiltrotor: calculate lateral position (BL) from RotorForEngine
SET_geom=rotor: (SL,BL,WL or XoL,YoL,ZoL) is relative loc_rotor(RotorForEngine)
SET_Swet, wetted area: input (use Swet) or calculated (from kSwet)
units of kSwet are ft^2/lb$^{2/3}$ or m^2/kg$^{2/3}$
$w = W_{ES}$ (engine system) or $W_{ES} + W_{gbrs}/N_{EG}$ (engine system and drive system)
nacelle wetted area used for nacelle drag, and for cowling weight
engine group nacelle must be consistent with rotor pylon

		Derived geometry
iDirection	int	nominal orientation (1, –1, 2, –2, 3, –3)
axis_incid	int	axis incidence (±123)
axis_yaw	int	axis yaw (±123)
isFixed	int	orientation (1 fixed)
CBF(3,3)	real	engine axes relative airframe, C^{BF} (fixed)
ef0(3)	real	engine direction, e_{f0}
ef(3)	real	engine direction, e_f (fixed)

		+	Controls	
		+	amplitude A (fixed engine group power)	
INPUT_amp	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_amp(ncontmax,nstatemax)	real	+	control matrix	
nVamp	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
amp(nvelmax)	real	+	values	
Vamp(nvelmax)	real	+	speeds (CAS or TAS)	
		+	mode B	
INPUT_mode	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_mode(ncontmax,nstatemax)	real	+	control matrix	
nVmode	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
mode(nvelmax)	real	+	values	
Vmode(nvelmax)	real	+	speeds (CAS or TAS)	
		+	incidence i (tilt)	
INPUT_incid	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax)	real	+	control matrix	
nVincid	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax)	real	+	values	
Vincid(nvelmax)	real	+	speeds (CAS or TAS)	
		+	yaw ψ	
INPUT_yaw	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_yaw(ncontmax,nstatemax)	real	+	control matrix	
nVyaw	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
yaw(nvelmax)	real	+	values	
Vyaw(nvelmax)	real	+	speeds (CAS or TAS)	
		+	gear ratio factor $f_{\rm gear}$ (variable speed transmission only)	
INPUT_fgear	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_fgear(ncontmax,nstatemax)	real	+	control matrix	
nVfgear	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
fgear(nvelmax)	real	+	values	
Vfgear(nvelmax)	real	+	speeds (CAS or TAS)	

---

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Nacelle Drag	
MODEL_drag	int	+	model (0 none, 1 standard)	1
Idrag	real	+	incidence angle i for helicopter nominal drag (deg; 0 for not tilt)	0.
DEngSys	DEngSys		standard model	
			Derived drag	
DoQC_nac	real		nacelle cruise drag, area $(D/q)_{\rm nac}$	
DoQH_nac	real		nacelle helicopter drag, area $(D/q)_{\rm nac}$	
DoQV_nac	real		nacelle vertical drag, area $(D/q)_{\rm nac}$	

---

component drag contributions must be consistent
pylon is rotor support, and nacelle is engine support
tiltrotor with tilting engines use pylon drag (and no nacelle drag),
since pylon connected to rotor shaft axes
tiltrotor with nontilting engines, use nacelle drag as well

		+	Weight	
Weight	Weight		weight statement (component, including engine weight)	
		+	engine weight	
MODEL_weight	int	+	model (0 input, 1 RPTEM or NASA, 2 custom)	1
dWEng	real	+	weight increment (all engines)	0.
		+	engine system (except engine), engine section or nacelle group, air induction group	
		+	model (0 input, 1 NDARC, 2 custom)	
MODEL_sys	int	+	engine system	1
MODEL_nac	int	+	engine section or nacelle	1
MODEL_air	int	+	air induction	1

		+	weight increment	
dWexh	real	+	exhaust	0.
dWacc	real	+	accessories	0.
dWsupt	real	+	engine support	0.
dWcowl	real	+	engine cowling	0.
dWpylon	real	+	pylon support	0.
dWair	real	+	air induction	0.
WEngSys	WEngSys		NDARC model	
Weng_total	real		engine weight	
WES	real		engine system weight W_{ES} (engine, exhaust, accessories)	
Wtip	real		weight on wing tip	
WESC	real		motor electronic speed control weight	
WTMS	real		motor thermal management system weight	
		+	Technology Factors	
TECH_eng	real	+	engine weight $\chi_{\rm eng}$	1.0
TECH_cowl	real	+	engine cowling weight $\chi_{\rm cowl}$	1.0
TECH_pylon	real	+	pylon structure weight $\chi_{\rm pylon}$	1.0
TECH_supt	real	+	engine support structure weight $\chi_{\rm supt}$	1.0
TECH_air	real	+	air induction system weight $\chi_{\rm airind}$	1.0
TECH_exh	real	+	exhaust system weight $\chi_{\rm exh}$	1.0
TECH_acc	real	+	engine accessories weight $\chi_{\rm acc}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

engine system weight = engine + exhaust + accessory (WES used for rotor pylon wetted area, engine nacelle wetted area, rotor moving weight)
nacelle weight = support + cowl + pylon
engine weight parameters in EngineModel

tiltrotor wing weight model requires weight on wing tip:
engine section or nacelle group, air induction group, engine system

---

Chapter 64

Structure: DEngSys

Variable	Type		Description	Default
		+	Nacelle Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	
CD	real	+	coefficient C_{D0} (based on wetted area, $D/q = SC_D$)	
		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient C_{DV} (based on wetted area, $D/q = SC_D$)	
		+	transition from forward flight drag to vertical drag	
MODEL_Deng	int	+	model (0 none)	1
Xdrag	real	+	exponent X_d	2.0

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

		+	Cooling Drag	
DoQ_cool	real	+	area $(D/q)_{\text{cool}}$	0.

Chapter 65

Structure: WEngSys

Variable	Type		Description	Default
		+	Engine Section or Nacelle Group, NDARC Weight Model	
MODEL_nacelle	int	+	model (1 parametric, 2 scale with power, 3 Boeing, 4 Raymer (transport))	1
fWpylon	real	+	pylon support structure weight $f_{\rm pylon}$ (fraction maximum takeoff weight)	0.
		+	nacelle group weight, W vs P_{0C}	
Knac	real	+	factor $K_{\rm nac}$	
Xnac	real	+	exponent $X_{\rm nac}$	
n_clf	real	+	Boeing: crash load factor	20.
fWidth_nac	real	+	Raymer: nacelle width (fraction nacelle length)	0.2
		+	Air Induction Group, NDARC Weight Model	
MODEL_airind	int	+	model (1 parametric, 2 area)	1
fWair	real	+	air induction weight $f_{\rm airind}$ (fraction engine support plus air induction weight)	0.3
Uair	real	+	weight per nacelle area $U_{\rm airind}$ (lb/ft^2 or kg/m^2)	
		+	Engine System, NDARC Model	
		+	exhaust system weight, per engine, including IR suppressor; $W_{\rm exh}$ vs P_{0C}	
Kwt0_exh	real	+	$K_{0\rm exh}$	0.
Kwt1_exh	real	+	$K_{1\rm exh}$	0.002
		+	engine accessories	
MODEL_lub	int	+	lubrication system weight (1 in engine weight, 2 in accessory weight)	1

---

typically fWair = 0.3 (data range 0.1 to 0.6)

engine support and pylon support weights must be consistent with rotor support structure weight

---

		+	Custom Weight Model	
WtParam_engsys(8)	real	+	parameters	0.

		Weight Model Input
		Exhaust
Neng_x	int	number of engines
Peng_x	real	installed takeoff power
		Accessory
Neng_a	int	number of engines
Weng_a	real	engine weight (all engines)
		Engine support
Neng_s	int	number of engines
Weng_s	real	engine weight (all engines)
		Cowling
Snac_c	real	nacelle wetted area
Neng_c	int	number of engines
Peng_c	real	installed takeoff power
Weng_c	real	engine weight (all engines)
		Pylon support
WMTO_p	real	maximum takeoff weight
		Air induction
Neng_i	int	number of engines
Weng_i	real	engine weight (all engines)
Snac_i	real	nacelle wetted area

Chapter 66

Structure: JetGroup

Variable	Type		Description	Default
		+	Jet Group	
title	c*100	+	title	
notes	c*1000	+	notes	
kJetGroup	int		jet group number	
		+	Description	
MODEL_jet	c*32	+	jet model	'RPJEM'
IDENT_jet	c*16	+	jet identification	'Jet'
IDENT_system2	c*16	+	second system identification	' '
nJet	int	+	number of jets N_{jet}	1
Tjet	real	+	jet thrust T_{jet} (SLS static at takeoff rating, 0. for T0_ref(rating_to))	0.
rating_to	c*12	+	takeoff thrust rating	'MCT'
rating_idle	c*12	+	idle thrust rating	'MCT'
kFuelTank	int	+	fuel tank system number	1
kRotor_react	int	+	rotor number for reaction drive	
fuselage_flow	int	+	fuselage flow control (0 not)	1
wing_flow(nwingmax)	int	+	wing flow control (0 not)	1
			Derived	
iMODEL_jet	int		jet model (MODEL_jet_xxx)	
KIND_jet	int		jet model (MODEL_jet_RPJEM, simple)	
isConvertReact	int		convertible engine (0 not)	
kModel_jet	int		identification (JetModel, from IDENT_jet)	
kModel_sys2	int		identification (JetModel, from IDENT_system2)	
nrate	int		number of ratings	
rating(nratemax)	c*12		rating designations (lowercase)	
krateC	int		MCT rating number	
krate_to	int		takeoff thrust rating number	
WOneJet	real		weight one jet $W_{\text{one jet}}$	

comp_flow	int		flow control, any component (0 none)	

MODEL_jet: jet model
'RPJEM', 'jet', 'fan' = turbojet/turbofan engine (RPJEM); IDENT_jet → JetModel; fuel is weight
'react' = reaction drive (RPJEM)); IDENT_jet → JetModel; fuel is weight
'flow' = flow control (RPJEM)); IDENT_jet → JetModel; fuel is weight
'simple' = simple force generator; no model identified; fuel is weight or energy
MODEL_jet: convertible engine; only with turbojet/turbofan
'+react' = reaction drive (mode $B = 1$); IDENT_system2 → JetModel

jet identification: match ident of JetModel
second system identification: match ident of JetModel; not use weight

for fixed jet: use $T_{\rm jet} = 0.$ and no size task (or jet thrust not sized)

			Jet model performance parameters (one jet)	
T0(nratemax)	real		thrust (T_0)	
ST0(nratemax)	real		specific thrust (ST_0)	
Tmech(nratemax)	real		mechanical limit of thrust ($T_{\rm mech}$)	
sfc0C	real		specific fuel consumption at MCT (${\rm sfc}_{0C}$)	
mdot0C	real		mass flow at MCT ($\dot{m}_{0C} = T_{0C}/ST_{0C}$)	
wdot0C	real		fuel flow at MCT ($\dot{w}_{0C} = {\rm sfc}_{0C} T_{0C}$)	
Edot0C	real		energy flow at MCT ($\dot{w}_{0C} = {\rm sfc}_{0C} T_{0C}$)	
			Jet model performance parameters (one jet), ratio converted to base	
rsfc0C_conv	real		specific fuel consumption at MCT	
rwdot0C_conv	real		fuel flow at MCT	
		+	Installation	
Kffd	real	+	deterioration factor on jet fuel flow K_{ffd}	1.05
eta_d	real	+	jet inlet efficiency η_d (fraction, for δ_M)	0.98
		+	power losses (fraction thrust available, $T_{\rm loss}/T_a$)	
fTloss_inlet	real	+	engine inlet loss ℓ_{in}	0.
fTloss_exh	real	+	engine exhaust loss ℓ_{ex} (IRS off)	0.01

		+	auxiliary air momentum drag (IRS off)	
fMF_auxair	real	+	mass flow $f_{\rm aux}$ (fraction engine mass flow)	0.007
eta_auxair	real	+	ram recovery efficiency $\eta_{\rm aux}$	0.75
		+	IR suppressor	
		+	power losses (IRS on)	
fTloss_exh_IRon	real	+	engine exhaust loss ℓ_{ex}	0.03
		+	auxiliary air momentum drag (IRS on)	
fMF_auxair_IRon	real	+	mass flow $f_{\rm aux}$ (fraction engine mass flow)	0.01
eta_auxair_IRon	real	+	ram recovery efficiency $\eta_{\rm aux}$	0.75
		+	Convertible	
Kffd_conv	real	+	deterioration factor on jet fuel flow K_{ffd}	1.05
		+	power losses (fraction thrust available, $T_{\rm loss}/T_a$)	
fTloss_exh_conv	real	+	engine exhaust loss ℓ_{ex}	0.01

installation power losses = inlet + exhaust (including IRS)
IR suppressor state specified by STATE_IRS_jet in operating condition

		+	Simple force generator	
Tmax	real	+	design maximum thrust $T_{\rm max}$	0.
SET_burn	int	+	fuel quantity used (1 weight, 2 energy)	1
sfc	real	+	thrust specific fuel consumption (weight or energy)	1.0
SW	real	+	specific weight S (per jet)	
KIND_simple	int	+	weight group (1 engine system, 2 propeller/fan installation, 3 tail rotor)	1

fuel tank system identified must be consistent with SET_burn

		+	Geometry	
loc_jet	Location	+	location	
direction	c*16	+	nominal orientation ('+x', '–x', '+y', '–y', '+z', '–z')	'x'

SET_Swet	int	+	nacelle/cowling wetted area (1 fixed, input Swet; 2 scaled)	2
Swet	real	+	area S_{wet} (per jet)	0.
kSwet	real	+	factor, $k = S_{\text{wet}}/(W_{ES}/N_{\text{jet}})^{2/3}$ (Units_Dscale)	0.8
Snac	real		nacelle/cowling area S_{nac}	
Swet_nac	real		total wetted area	

SET_Swet, wetted area: input (use Swet) or calculated (from kSwet)
units of kSwet are ft^2/lb$^{2/3}$ or m^2/kg$^{2/3}$
nacelle wetted area used for nacelle drag, and for cowling weight

			Derived geometry	
iDirection	int		nominal orientation (1, –1, 2, –2, 3, –3)	
axis_incid	int		axis incidence (±123)	
axis_yaw	int		axis yaw (±123)	
isFixed	int		orientation (1 fixed)	
CBF(3,3)	real		jet relative airframe, C^{BF} (fixed)	
ef0(3)	real		jet direction, e_{f0}	
ef(3)	real		jet direction, e_f (fixed)	
		+	Controls	
		+	amplitude A	
INPUT_amp	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_amp(ncontmax,nstatemax)	real	+	control matrix	
nVamp	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
amp(nvelmax)	real	+	values	
Vamp(nvelmax)	real	+	speeds (CAS or TAS)	
		+	mode B	
INPUT_mode	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_mode(ncontmax,nstatemax)	real	+	control matrix	
nVmode	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
mode(nvelmax)	real	+	values	
Vmode(nvelmax)	real	+	speeds (CAS or TAS)	

		+	incidence i (tilt)	
INPUT_incid	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax)	real	+	control matrix	
nVincid	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax)	real	+	values	
Vincid(nvelmax)	real	+	speeds (CAS or TAS)	
		+	yaw ψ	
INPUT_yaw	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_yaw(ncontmax,nstatemax)	real	+	control matrix	
nVyaw	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
yaw(nvelmax)	real	+	values	
Vyaw(nvelmax)	real	+	speeds (CAS or TAS)	

---

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Nacelle Drag	
MODEL_drag	int	+	model (0 none, 1 standard)	1
Idrag	real	+	incidence angle i for helicopter nominal drag (deg; 0 for not tilt)	0.
DJetSys	DJetSys		standard model	
			Derived drag	
DoQC_nac	real		nacelle cruise drag, area $(D/q)_{\rm nac}$	
DoQH_nac	real		nacelle helicopter drag, area $(D/q)_{\rm nac}$	
DoQV_nac	real		nacelle vertical drag, area $(D/q)_{\rm nac}$	

		+	Weight	
Weight	Weight		weight statement (component, including jet weight)	
		+	jet weight	
MODEL_weight	int	+	model (0 input, 1 RPJEM, 2 custom)	1
dWJet	real	+	weight increment (all jets)	0.
		+	engine system (except jet), engine section or nacelle group, air induction group	
		+	model (0 input, 1 NDARC, 2 custom)	
MODEL_sys	int	+	engine system	1
MODEL_nac	int	+	engine section or nacelle	1
MODEL_air	int	+	air induction	1
		+	weight increment	
dWexh	real	+	exhaust	0.
dWacc	real	+	accessories	0.
dWsupt	real	+	engine support	0.
dWcowl	real	+	engine cowling	0.
dWpylon	real	+	pylon support	0.
dWair	real	+	air induction	0.
WJetSys	WJetSys		NDARC model	
Wjet_total	real		jet weight	
WES	real		engine system weight W_{ES} (engine, exhaust, accessories)	
		+	Technology Factors	
TECH_jet	real	+	jet weight $\chi_{\rm jet}$	1.0
TECH_jetcowl	real	+	engine cowling weight $\chi_{\rm cowl}$	1.0
TECH_jetpylon	real	+	pylon structure weight $\chi_{\rm pylon}$	1.0
TECH_jetsupt	real	+	engine support structure weight $\chi_{\rm supt}$	1.0
TECH_jetair	real	+	air induction system weight $\chi_{\rm airind}$	1.0
TECH_jetexh	real	+	exhaust system weight $\chi_{\rm exh}$	1.0
TECH_jetacc	real	+	engine accessories weight $\chi_{\rm acc}$	1.0

---

weight model result multiplied by technology factor and increment added:

Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

engine system weight = engine + exhaust + accessory (WES used for nacelle wetted area)

nacelle weight = support + cowl + pylon

jet weight parameters in JetModel

Chapter 67

Structure: DJetSys

Variable	Type		Description	Default
		+	Nacelle Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	
CD	real	+	coefficient C_{D0} (based on wetted area, $D/q = SC_D$)	
		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient C_{DV} (based on wetted area, $D/q = SC_D$)	
		+	transition from forward flight drag to vertical drag	
MODEL_Djet	int	+	model (0 none)	1
Xdrag	real	+	exponent X_d	2.0

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

Variable	Type		Description	Default
		+	Cooling Drag	
DoQ_cool	real	+	area $(D/q)_{\text{cool}}$	0.

Chapter 68

Structure: WJetSys

Variable	Type		Description	Default
		+	Engine Section or Nacelle Group, NDARC Weight Model	
MODEL_nacelle	int	+	model (1 parametric, 2 scale with thrust, 3 Boeing, 4 Raymer (transport))	1
fWpylon	real	+	pylon support structure weight f_{pylon} (fraction maximum takeoff weight)	0.
		+	nacelle group weight, W vs T_{0C}	
Knac	real	+	factor K_{nac}	
Xnac	real	+	exponent X_{nac}	
n_clf	real	+	Boeing: crash load factor	20.
fWidth_nac	real	+	Raymer: nacelle width (fraction nacelle length)	0.2
		+	Air Induction Group, NDARC Weight Model	
MODEL_airind	int	+	model (1 parametric, 2 area)	1
fWair	real	+	air induction weight f_{airind} (fraction engine support plus air induction weight)	0.3
Uair	real	+	weight per nacelle area U_{airind} (lb/ft^2 or kg/m^2)	
		+	Engine System, NDARC Model	
		+	exhaust system weight, per jet; W_{exh} vs T_{0C}	
Kwt0_exh	real	+	$K_{0\text{exh}}$	0.
Kwt1_exh	real	+	$K_{1\text{exh}}$	0.002
		+	engine accessories	
MODEL_lub	int	+	lubrication system weight (1 in jet weight, 2 in accessory weight)	1
		+	Custom Weight Model	
WtParam_jetsys(8)	real	+	parameters	0.
			Weight Model Input	
			Exhaust	
Njet_x	int		number of engines	
Tjet_x	real		installed takeoff thrust	
			Accessory	
Njet_a	int		number of engines	
Wjet_a	real		jet weight (all jets)	

		Engine support
Njet_s	int	number of engines
Wjet_s	real	jet weight (all jets)
		Cowling
Snac_c	real	nacelle wetted area
Njet_c	int	number of engines
Tjet_c	real	installed takeoff thrust
Wjet_c	real	jet weight (all jets)
		Pylon support
WMTO_p	real	maximum takeoff weight
		Air induction
Njet_i	int	number of engines
Wjet_i	real	jet weight (all jets)
Snac_i	real	nacelle wetted area

Chapter 69

Structure: ChargeGroup

Variable	Type		Description	Default
		+	Charge Group	
title	c*100	+	title	
notes	c*1000	+	notes	
kChargeGroup	int		charge group number	
		+	Description	
MODEL_charge	c*32	+	charger model	' '
IDENT_charge	c*16	+	charger identification	'Charge'
nCharge	int	+	number of chargers N_{chrg}	1
Pchrg	real	+	charger power P_{chrg} (SLS static at takeoff rating, 0. for P0_ref(rating_to))	0.
rating_to	c*12	+	takeoff power rating	'MCP'
rating_idle	c*12	+	idle power rating	'MCP'
kFuelTank	int	+	fuel tank system number (generated)	1
kFuelTank_burn	int	+	fuel tank system number (burned)	
			Derived	
iMODEL_charge	int		charger model (MODEL_charge_xxx)	
KIND_charge	int		charger model (MODEL_charge_fuelcell, solarcell, simple)	
kModel_chrg	int		identification (FuelCellModel or SolarCellModel, from IDENT_charge)	
kBattery	int		battery model, from kFuelTank (0 for none)	
nrate	int		number of ratings	
rating(nratemax)	c*12		rating designations (lowercase)	
krateC	int		MCP rating number	
krate_to	int		takeoff power rating number	
WOneChrg	real		weight one charger $W_{\text{one chrg}}$	

MODEL_charge: charger model
- 'fuel' = fuel cell; IDENT_charge → FuelCellModel; fuel generated is energy; fuel burned is weight (kFuelTank_burn)
- 'solar' = solar cell; IDENT_charge → SolarCellModel; fuel generated is energy
- 'simple' = simple charger; no model identified; fuel generated is energy

charger identification: match ident of FuelCellModel or SolarCellModel

for fixed charger: use $P_{\rm chrg} = 0.$ and no size task (or charger power not sized)

fuel tank system identified for generation must store and use energy (may have BatteryModel)
fuel tank system identified for burn must store and use weight

---

			Charger model performance parameters (one charger)	
P0(nratemax)	real		power (P_0)	
sfc0C	real		specific fuel consumption at MCP (sfc_{0C})	
mdot0C	real		mass flow at MCP ($\dot{m}_{0C}$)	
wdot0C	real		fuel flow at MCP ($\dot{w}_{0C} = \mathrm{sfc}_{0C} P_{0C}$)	
solararea	real		solar cell total area	
		+	Installation	
Kffd	real	+	deterioration factor on charger fuel flow or performance K_{ffd}	1.05
eta_d	real	+	charger inlet efficiency η_d (fraction, for δ_M)	0.98
		+	auxiliary air momentum drag	
fMF_auxair	real	+	mass flow $f_{\rm aux}$ (fraction charger mass flow)	0.007
eta_auxair	real	+	ram recovery efficiency $\eta_{\rm aux}$	0.75
		+	Simple charger	
Pmax	real	+	design maximum power $P_{\rm max}$	0.
eta_chrg	real	+	efficiency $\eta_{\rm chrg}$	1.0
SW	real	+	specific weight S (per charger)	
		+	Geometry	
loc_charger	Location	+	location	
direction	c*16	+	nominal orientation ('+x', '–x', '+y', '–y', '+z', '–z')	'x'
SET_Swet	int	+	nacelle/cowling wetted area (1 fixed, input Swet; 2 scaled)	2
Swet	real	+	area $S_{\rm wet}$ (per charger)	0.
kSwet	real	+	factor, $k = S_{\rm wet}/(W/N_{\rm chrg})^{2/3}$ (Units_Dscale)	0.8
Snac	real		nacelle/cowling area $S_{\rm nac}$	
Swet_nac	real		total wetted area	

SET_Swet, wetted area: input (use Swet) or calculated (from kSwet)
units of kSwet are $ft^2/lb^{2/3}$ or $m^2/kg^{2/3}$
nacelle wetted area used for nacelle drag

			Derived geometry	
iDirection	int		nominal orientation (1, –1, 2, –2, 3, –3)	
axis_incid	int		axis incidence (±123)	
axis_yaw	int		axis yaw (±123)	
isFixed	int		orientation (1 fixed)	
CBF(3,3)	real		charger relative airframe, C^{BF} (fixed)	
ef0(3)	real		charger direction, e_{f0}	
ef(3)	real		charger direction, e_f (fixed)	
		+	Controls	
		+	amplitude A	
INPUT_amp	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_amp(ncontmax,nstatemax)	real	+	control matrix	
nVamp	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
amp(nvelmax)	real	+	values	
Vamp(nvelmax)	real	+	speeds (CAS or TAS)	
		+	mode B	
INPUT_mode	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_mode(ncontmax,nstatemax)	real	+	control matrix	
nVmode	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
mode(nvelmax)	real	+	values	
Vmode(nvelmax)	real	+	speeds (CAS or TAS)	
		+	incidence i (tilt)	
INPUT_incid	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_incid(ncontmax,nstatemax)	real	+	control matrix	
nVincid	int	+	number of speeds (0 zero value; 1 constant; $\geq$ 2 piecewise linear, maximum nvelmax)	0
incid(nvelmax)	real	+	values	
Vincid(nvelmax)	real	+	speeds (CAS or TAS)	

		+	yaw ψ	
INPUT_yaw	int	+	connection to aircraft controls (0 none, 1 input T matrix)	1
T_yaw(ncontmax,nstatemax)	real	+	control matrix	
nVyaw	int	+	number of speeds (0 zero value; 1 constant; ≥ 2 piecewise linear, maximum nvelmax)	0
yaw(nvelmax)	real	+	values	
Vyaw(nvelmax)	real	+	speeds (CAS or TAS)	

---

aircraft controls connected to individual controls of component, $c = Tc_{AC} + c_0$
for each component control, define matrix T (for each control state) and value c_0
flight state specifies control state, or that control state obtained from conversion schedule
c_0 can be zero, constant, or function of flight speed (CAS or TAS, piecewise linear input)
by connecting aircraft control to comp control, flight state can specify comp control value
initial values if control is connected to trim variable; otherwise fixed for flight state

---

		+	Nacelle Drag	
MODEL_drag	int	+	model (0 none, 1 standard)	1
Idrag	real	+	incidence angle i for helicopter nominal drag (deg; 0 for not tilt)	0.
DChrgSys	DChrgSys		standard model	
			Derived drag	
DoQC_nac	real		nacelle cruise drag, area $(D/q)_{\rm nac}$	
DoQH_nac	real		nacelle helicopter drag, area $(D/q)_{\rm nac}$	
DoQV_nac	real		nacelle vertical drag, area $(D/q)_{\rm nac}$	
		+	Weight	
Weight	Weight		weight statement (component, including charger weight)	
		+	charger weight	
MODEL_weight	int	+	model (0 input, 1 NDARC, 2 custom)	1
dWChrg	real	+	weight increment (all chargers)	0.
WChrgSys	WChrgSys		NDARC model	
Wchrg_total	real		charge group weight	
WES	real		engine system weight W_{ES} (engine, exhaust, accessories)	

		+	Technology Factors	
TECH_chrg	real	+	charger weight $\chi_{\rm chrg}$	1.0

---

weight model result multiplied by technology factor and increment added:
Wxx = TECH_xx*Wxx_model + dWxx; for fixed (input) weight use MODEL_xx=0 or TECH_xx=0.

engine system weight = engine + exhaust + accessory = charge group weight (WES used for nacelle wetted area)
charger weight parameters in FuelCellModel or SolarCellModel

Chapter 70

Structure: DChrgSys

Variable	Type		Description	Default
		+	Nacelle Drag, Standard Model	
		+	forward flight drag	
SET_drag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQ	real	+	area $(D/q)_0$	
CD	real	+	coefficient C_{D0} (based on wetted area, $D/q = SC_D$)	
		+	vertical drag	
SET_Vdrag	int	+	specification (1 fixed, D/q; 2 scaled, C_D)	2
DoQV	real	+	area $(D/q)_V$	
CDV	real	+	coefficient C_{DV} (based on wetted area, $D/q = SC_D$)	
		+	transition from forward flight drag to vertical drag	
MODEL_Dchrg	int	+	model (0 none)	1
Xdrag	real	+	exponent X_d	2.0

SET_xxx: fixed (use DoQ) or scaled (use CD); other parameter calculated

		+	Cooling Drag	
DoQ_cool	real	+	area $(D/q)_{\rm cool}$	0.

Chapter 71

Structure: WChrgSys

Variable	Type		Description	Default
		+	Custom Weight Model	
WtParam_chrgsys(8)	real	+	parameters	0.

Chapter 72

Structure: EngineModel

Variable	Type		Description	Default
		+	Engine Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Engine'

engine identification: used by IDENT_engine of EngineGroup input (eg 'T800')

installed: power available P_{av}, power required P_{req}, gross jet thrust F_G, net jet thrust F_N
uninstalled: power available P_a, power required P_q, gross jet thrust F_g, net jet thrust F_n
"0" = SLS static; "C" = MCP
mass flow = power / specific power ($SP = P/\dot{m}$); fuel flow = specific fuel consumption * power ($\mathrm{sfc} = \dot{w}/P$)

engine model can be used by more than one engine group, so all parameters fixed

as model for turbojet or reaction drive of convertible engine:
only use sfc0C_ref, sfc0C_ref, and parameters for optimum speed, thrust available, and performance
P0_ref and SP0_ref required, but not used; weight, ratings, technology, and scaling variables not used

Variable	Type		Description	Default
kEngineModel	int		engine model number	
		+	Weight	
MODEL_weight	int	+	RPTEM model (0 fixed, 1 $W(P)$, 2 $SW(\dot{m})$)	1
Weng	real	+	engine weight (fixed)	0.
		+	engine weight, $W_{\rm eng}$ vs $P_{\rm eng}$ model ($W = K_{0\rm eng} + K_{1\rm eng}P + K_{2\rm eng}P^{X_{\rm eng}}$)	
Kwt0_eng	real	+	constant $K_{0\rm eng}$	0.
Kwt1_eng	real	+	constant $K_{1\rm eng}$	0.25
Kwt2_eng	real	+	constant $K_{2\rm eng}$	0.
Xwt_eng	real	+	exponent $X_{\rm eng}$	0.

		+	engine weight, $SW = P_{\rm eng}/W_{\rm eng}$ vs $\dot{m}_{0C}$ model	
SW_ref	real	+	specific weight reference $SW_{\rm ref}$ ($\dot{m} = \dot{m}_{\rm tech}$)	4.
SW_limit	real	+	specific weight limit $SW_{\rm lim}$ ($\dot{m} = \dot{m}_{\rm lim}$)	5.
		+	Custom Weight Model	
WtParam_engine(8)	real	+	parameters	0.
		+	Parameters	
		+	Engine Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	2000.
SP0_ref(nratemax)	real	+	specific power (SP_0)	150.
Pmech_ref(nratemax)	real	+	mechanical limit of power ($P_{\rm mech}$)	2500.
sfc0C_ref	real	+	specific fuel consumption at MCP (${\rm sfc}_{0C}$)	0.45
SF0C_ref	real	+	specific jet thrust ($F_{g0C} = SF_{0C}\dot{m}_{0C}$)	10.
Nspec_ref	real	+	specification turbine speed ($N_{\rm spec}$)	20000.
Nopt0C_ref	real	+	optimum turbine speed at MCP ($N_{\rm opt0C}$)	20000.
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	
rSP0(nratemax)	real		specific power (SP_{0R}/SP_{0C})	
rPmech(nratemax)	real		mechanical limit of power ($P_{{\rm mech}R}/P_{0C}$)	

Reference Engine Rating: SLS, static
    if MCP scaled, ratios to MCP values kept constant
engine rating: match rating designation in FltState; typically designated as
    'ERP' = Emergency Rated Power (OEI power)
    'CRP' = Contigency Rated Power (2.5 min)
    'MRP' = Maximum Rated Power (5 or 10 min)
    'IRP' = Intermediate Rated Power (30 min)
    'MCP' = Maximum Continuous Power (normal operations)
    engine model being used may not contain data for all ratings

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		+	Technology	
SP0C_tech	real	+	specific power at MCP $SP_{\rm tech}$ (0. for SP0_ref(MCP))	0.
sfc0C_tech	real	+	specific fuel consumption at MCP $\text{sfc}_{\rm tech}$ (0. for sfc0C_ref)	0.
Nspec_tech	real	+	specification turbine speed $N_{\rm tech}$ (0. for Nspec_ref)	0.
		+	Scaling	
FIX_size	int	+	engine size (0 scaled, 1 fixed)	0
MF_limit	real	+	mass flow at limit SP and sfc ($\dot{m}_{\rm lim}$)	30.
SP0C_limit	real	+	specific power limit $SP_{\rm lim}$	200.
sfc0C_limit	real	+	specific fuel consumption limit $\text{sfc}_{\rm lim}$	0.34
KNspec	real	+	specification turbine speed variation (K_{Ns2})	0.
			Derived scaling	
			specific power available (SLS static, MCP, $N_{\rm spec}$), SP_{0C} vs $\dot{m}_{0C}$	
P0C_limit	real		power limit	
Ksp0	real		K_{sp0}	
Ksp1	real		K_{sp1}	
			specific fuel consumption (SLS static, MCP, $N_{\rm spec}$), sfc_{0C} vs $\dot{m}_{0C}$	
Ksfc0	real		K_{sfc0}	
Ksfc1	real		K_{sfc1}	
			specification turbine speed, $N_{\rm spec}$ vs $\dot{m}_{0C}$	
KNs1	real		K_{Ns1}	
KNs2	real		K_{Ns2}	
			optimum turbine speed, $N_{{\rm opt}0C}$	
KNo	real		K_{No}	
			engine weight, $SW = P/W_{\rm eng}$ vs $\dot{m}_{0C}$	
Ksw0	real		K_{sw0}	
Ksw1	real		K_{sw1}	

SP and sfc functions are defined by values SP0C_tech, sfc0C_tech, $\dot{m}_{\rm tech}$=P0C_ref/SP0C_tech
and limits SP0C_limit, sfc0C_limit, MF_limit
defaults SP0C_tech=SP0_ref(MCP), sfc0C_tech=sfc0C_ref, Nspec_tech=Nspec_ref
require $\dot{m}_{\rm tech} < \dot{m}_{\rm lim}$ (otherwise get SP_{0C} = SP0C_tech and sfc_{0C} = sfc0C_tech)

for no variation of SP, sfc, and SW with scale, use FIX_size=1 or MF_limit=0.
engine weight scaling determined by MODEL_weight

		+	Optimum Power Turbine Speed	
MODEL_OptN	int	+	model (0 none, 1 linear, 2 cubic)	1
		+	linear, $N_{\rm opt}/N_{\rm spec}$ vs P_q/P_0	
KNoptA	real	+	constant $K_{N{\rm opt}A}$	1.
KNoptB	real	+	constant $K_{N{\rm opt}B}$	0.
		+	cubic, $N_{\rm opt}/N_{{\rm opt}0C}$ vs P_q/P_{0C}	
KNopt0	real	+	constant $K_{N{\rm opt}0}$	1.
KNopt1	real	+	constant $K_{N{\rm opt}1}$	0.
KNopt2	real	+	constant $K_{N{\rm opt}2}$	0.
KNopt3	real	+	constant $K_{N{\rm opt}3}$	0.
XNopt	real	+	exponent $X_{N{\rm opt}}$	0.
		+	power turbine efficiency function, $\eta_t(N)/\eta_t(N_{\rm spec})$	
XNeta	real	+	exponent $X_{N\eta}$	2.0

---

engine power and performance variation with power turbine speed determined by $N_{\rm opt}$ and $X_{N\eta}$
used only for INPUT_param = single set; no variation if MODEL_OptN=0

		+	Power Available and Power Required Parameters	
MODEL_Pav	int	+	power available (0 constant, 1 referred, 2 general)	2
MODEL_perf	int	+	performance at power required (1 referred, 2 general)	2
INPUT_param	int	+	parameter input form (1 single set; 2 function of engine speed)	1
Param	EngineParamN		single set (input moved to Param for use)	
		+	function of engine speed	
nspeed	int	+	number of engine speeds (maximum nspeedmax)	1
rNeng(nspeedmax)	real	+	engine speed ratio, $N/N_{\rm spec}$	1.
kEngineParamN(nspeedmax)	int	+	identification of parameter sets	1

---

constant or referred model does not use parameters, does not include effect of turbine speed
general model uses parameters for effects of temperature and ram, can include effect of turbine speed

function of engine speed (INPUT_param=2): parameters interpolated, rNeng unique and sequential

simple model: constant (MODEL_Pav=0) or constant referred (MODEL_Pav=1) power available
constant specific fuel consumption (MODEL_perf=1, sfc0C_tech=0., MF_limit=0.)
no jet force (EngineGroup%SET_FN=0), no auxiliary air momentum drag (EngineGroup%SET_Daux=0)

		+	Power Available	
INPUT_lin	int	+	input form (1 coefficients K_0, K_1; 2 values θ_b, K_b)	1
		+	referred specific power available, SP_a/SP_0 vs temperature	
Nspa(nratemax)	int	+	number of regions (maximum nengkmax-1)	0
Kspa0(nengkmax,nratemax)	real	+	K_{spa0} (piecewise linear $K_{spa} = K_0 + K_1\theta$)	3.5
Kspa1(nengkmax,nratemax)	real	+	K_{spa1} (piecewise linear $K_{spa} = K_0 + K_1\theta$)	-2.5
Tspak(nengkmax,nratemax)	real	+	θ_b	
Kspab(nengkmax,nratemax)	real	+	K_{spa-b}	
Xspa0(nengkmax,nratemax)	real	+	X_{spa0} (piecewise linear $X_{spa} = X_0 + X_1\theta$)	-.2
Xspa1(nengkmax,nratemax)	real	+	X_{spa1} (piecewise linear $X_{spa} = X_0 + X_1\theta$)	0.
Tspax(nengkmax,nratemax)	real	+	θ_b	
Xspab(nengkmax,nratemax)	real	+	X_{spa-b}	
		+	referred mass flow at power available, $\dot{m}_a/\dot{m}_0$ vs temperature	
Nmfa(nratemax)	int	+	number of regions (maximum nengkmax-1)	0
Kmfa0(nengkmax,nratemax)	real	+	K_{mfa0} (piecewise linear $K_{mfa} = K_0 + K_1\theta$)	.3
Kmfa1(nengkmax,nratemax)	real	+	K_{mfa1} (piecewise linear $K_{mfa} = K_0 + K_1\theta$)	-.3
Tmfak(nengkmax,nratemax)	real	+	θ_b	
Kmfab(nengkmax,nratemax)	real	+	K_{mfa-b}	
Xmfa0(nengkmax,nratemax)	real	+	X_{mfa0} (piecewise linear $X_{mfa} = X_0 + X_1\theta$)	1.
Xmfa1(nengkmax,nratemax)	real	+	X_{mfa1} (piecewise linear $X_{mfa} = X_0 + X_1\theta$)	0.
Tmfax(nengkmax,nratemax)	real	+	θ_b	
Xmfab(nengkmax,nratemax)	real	+	X_{mfa-b}	

---

piecewise linear function:
input form = coefficients K_0, K_1 (N sets) or values θ_b, K_b (N+1 values)
form not input is calculated (N-1 θ_b, K_b or N K_0, K_1)
input K_0, K_1: adjacent K_1 different, resulting θ_b unique and sequential
input θ_b, K_b: θ_b unique and sequential

N_{spec} = specification power turbine speed
$SP_a, \dot{m}_a$ = referred specific power and mass flow available, at N_{spec}
$SP_0, \dot{m}_0$ = referred specific power and mass flow available, at N_{spec}, SLS static
N = power turbine speed, N_{opt} = optimum power turbine speed
η_t = power turbine efficiency; assume gas power available $P_G = P_a/\eta_t$ insensitive to N, so $\eta_t(N)$ give $P_a(N)$

		+	Performance at Power Required	
		+	referred fuel flow at power required, $\dot{w}_{req}/\dot{w}_{0C}$ vs P_q/P_{0C}	
Kffq0	real	+	constant K_{ffq0}	.2
Kffq1	real	+	constant K_{ffq1}	.8
Kffq2	real	+	constant K_{ffq2}	0.
Kffq3	real	+	constant K_{ffq3}	0.
Xffq	real	+	exponent X_{ffq}	1.3
		+	referred mass flow at power required, $\dot{m}_{req}/\dot{m}_{0C}$ vs P_q/P_{0C}	
Kmfq0	real	+	constant K_{mfq0}	.6
Kmfq1	real	+	constant K_{mfq1}	.78
Kmfq2	real	+	constant K_{mfq2}	-.48
Kmfq3	real	+	constant K_{mfq3}	.1
Xmfq	real	+	exponent X_{mfq}	3.5
		+	gross jet thrust at power required, F_g/F_{g0C} vs P_q/P_{0C}	
Kfgq0	real	+	constant K_{fgq0}	.2
Kfgq1	real	+	constant K_{fgq1}	.8
Kfgq2	real	+	constant K_{fgq2}	0.
Kfgq3	real	+	constant K_{fgq3}	0.
Xfgq	real	+	exponent X_{fgq}	2.0
		+	installed net jet thrust at power required, F_G/F_g (installed thrust loss) vs ℓ_{ex}	
Kfgr0	real	+	constant K_{fgr0}	.8
Kfgr1	real	+	constant K_{fgr1}	.6
Kfgr2	real	+	constant K_{fgr2}	0.
Kfgr3	real	+	constant K_{fgr3}	0.

Chapter 73

Structure: EngineParamN

Variable	Type		Description	Default
		+	Engine Model Parameters	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
kEngineParamN	int		engine param number	
		+	Power Available	
nrate	int	+	number of ratings	1
INPUT_lin	int	+	input form (1 coefficients K_0, K_1; 2 values θ_b, K_b)	1
		+	referred specific power available, SP_a/SP_0 vs temperature	
Nspa(nratemax)	int	+	number of regions (maximum nengkmax-1)	0
Kspa0(nengkmax,nratemax)	real	+	K_{spa0} (piecewise linear $K_{spa} = K_0 + K_1\theta$)	3.5
Kspa1(nengkmax,nratemax)	real	+	K_{spa1} (piecewise linear $K_{spa} = K_0 + K_1\theta$)	-2.5
Tspak(nengkmax,nratemax)	real	+	θ_b	
Kspab(nengkmax,nratemax)	real	+	K_{spa-b}	
Xspa0(nengkmax,nratemax)	real	+	X_{spa0} (piecewise linear $X_{spa} = X_0 + X_1\theta$)	-.2
Xspa1(nengkmax,nratemax)	real	+	X_{spa1} (piecewise linear $X_{spa} = X_0 + X_1\theta$)	0.
Tspax(nengkmax,nratemax)	real	+	θ_b	
Xspab(nengkmax,nratemax)	real	+	X_{spa-b}	
		+	referred mass flow at power available, $\dot{m}_a/\dot{m}_0$ vs temperature	
Nmfa(nratemax)	int	+	number of regions (maximum nengkmax-1)	0
Kmfa0(nengkmax,nratemax)	real	+	K_{mfa0} (piecewise linear $K_{mfa} = K_0 + K_1\theta$)	.3
Kmfa1(nengkmax,nratemax)	real	+	K_{mfa1} (piecewise linear $K_{mfa} = K_0 + K_1\theta$)	-.3
Tmfak(nengkmax,nratemax)	real	+	θ_b	
Kmfab(nengkmax,nratemax)	real	+	K_{mfa-b}	
Xmfa0(nengkmax,nratemax)	real	+	X_{mfa0} (piecewise linear $X_{mfa} = X_0 + X_1\theta$)	1.
Xmfa1(nengkmax,nratemax)	real	+	X_{mfa1} (piecewise linear $X_{mfa} = X_0 + X_1\theta$)	0.
Tmfax(nengkmax,nratemax)	real	+	θ_b	
Xmfab(nengkmax,nratemax)	real	+	X_{mfa-b}	

number of ratings consistent with EngineModel

		+	Performance at Power Required	
		+	referred fuel flow at power required, $\dot{w}_{req}/\dot{w}_{0C}$ vs P_q/P_{0C}	
Kffq0	real	+	constant K_{ffq0}	.2
Kffq1	real	+	constant K_{ffq1}	.8
Kffq2	real	+	constant K_{ffq2}	0.
Kffq3	real	+	constant K_{ffq3}	0.
Xffq	real	+	exponent X_{ffq}	1.3
		+	referred mass flow at power required, $\dot{m}_{req}/\dot{m}_{0C}$ vs P_q/P_{0C}	
Kmfq0	real	+	constant K_{mfq0}	.6
Kmfq1	real	+	constant K_{mfq1}	.78
Kmfq2	real	+	constant K_{mfq2}	-.48
Kmfq3	real	+	constant K_{mfq3}	.1
Xmfq	real	+	exponent X_{mfq}	3.5
		+	gross jet thrust at power required, F_g/F_{g0C} vs P_q/P_{0C}	
Kfgq0	real	+	constant K_{fgq0}	.2
Kfgq1	real	+	constant K_{fgq1}	.8
Kfgq2	real	+	constant K_{fgq2}	0.
Kfgq3	real	+	constant K_{fgq3}	0.
Xfgq	real	+	exponent X_{fgq}	2.0
		+	installed net jet thrust at power required, F_G/F_g (installed thrust loss) vs ℓ_{ex}	
Kfgr0	real	+	constant K_{fgr0}	.8
Kfgr1	real	+	constant K_{fgr1}	.6
Kfgr2	real	+	constant K_{fgr2}	0.
Kfgr3	real	+	constant K_{fgr3}	0.
			Derived	
q(41)	real		referred power P_q/P_{0C} (0. to 4.0)	
fgq(41)	real		gross jet thrust F_g/F_{g0C}	
mfq(41)	real		referred mass flow $\dot{m}_{req}/\dot{m}_{0C}$	

Chapter 74

Structure: EngineTable

Variable	Type		Description	Default
		+	Engine Table	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Engine'

engine identification: used by IDENT_engine of EngineGroup input

engine table can be used by more than one engine group, so all parameters fixed

engine not scaled (SET_power, fPsize not used); eta_d not used
fixed engine weight dWEng (MODEL_weight=0)
no mass flow value, so no momentum drag of auxillary air flow (fMF_auxair, eta_auxair not used)
obtain Peng from table; mechanical limits included in power available data
tables intended for installed engine, including losses (fPloss_inlet, fPloss_ps, fPloss_exh not used)
fuel flow multiplied by Kffd, accounting for deterioration of engine efficiency

Variable	Type		Description	Default
kEngineTable	int		engine table number	
		+	Engine ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
Nspec	real	+	Specification turbine speed ($N_{\rm spec}$)	

		+	Table	
KIND_table	int	+	format (1 E, 2 H)	1
nalt	int	+	number of altitudes (maximum nengtmax)	
ntemp	int	+	number of temperatures (maximum nengxmax)	
nspeed	int	+	number of speeds (maximum nengtmax)	
nalt_ram	int	+	number of altitudes for $f_{\rm RAM}$ (maximum nengtmax)	
ntemp_ram	int	+	number of temperatures for $f_{\rm RAM}$ (maximum nengxmax)	
alt(nengtmax)	real	+	altitude h	
temp(nengxmax)	real	+	temperature τ	
speed(nengtmax)	real	+	speed V (TAS)	
alt_ram(nengtmax)	real	+	altitude h for $f_{\rm RAM}$	
temp_ram(nengxmax)	real	+	temperature τ for $f_{\rm RAM}$	

table format E: use alt, speed
table format H: use alt, temp; and for $f_{\rm RAM}$ use speed, alt_ram, temp_ram; no jet thrust

		+	Technology factors	
Kp	real	+	power available	1.0
Kw	real	+	fuel flow	1.0
Kf	real	+	net thrust	1.0
		+	Table format E	
Tp(nengtmax,nengtmax,nratemax)	real	+	power available $P_a(h,V,R)$	
Tw(nengtmax,nengtmax,nratemax)	real	+	fuel flow $\dot{w}(h,V,R)$	
Tf(nengtmax,nengtmax,nratemax)	real	+	net thrust $F_N(h,V,R)$	
		+	Table format H	
KIND_temp	int	+	temperature units (0 F or C based on Units; 1 F, 2 C)	0
change_temp	int		change temperature units (0 not, 1 F to C, 2 C to F)	

		+	power available	
P0(nengtmax,nengxmax,nratemax)	real	+	static power $P_0(h,\tau,R)$	
KIND_ram	int	+	ram factor (1 table, 2 referred)	1
fRAM(nengtmax,nengxmax,nengtmax)	real	+	table ram factor $f_{\rm RAM}(V,\tau,h)$	
Xpa(nratemax)	real	+	referred ram factor $f_{\rm RAM}=(\delta_M\sqrt{\theta_M})^{X_{pa}}$, exponent X_{pa}	1.
		+	fuel flow	
KIND_fuelflow	int	+	kind (1 reference $\dot{w}_{\rm ref}(P_{q\rm ref})$, 2 table $\dot{w}(P_q,h,\tau)$)	1
		+	reference	
nfuelflow	int	+	number of fuel flow values (maximum nengxmax)	
Pq_ref(nengxmax)	real	+	reference power required $P_q/\delta^{X_{dp}}\theta^{X_{rp}}$	
ff_ref(nengxmax)	real	+	reference fuel flow $\dot{w}/\delta^{X_{df}}\theta^{X_{rf}}$	
Xdp	real	+	reference power, pressure exponent X_{dp}	1.0
Xrp	real	+	reference power, temperature exponent X_{rp}	0.5
Xdf	real	+	reference fuel flow, pressure exponent X_{df}	1.0
Xrf	real	+	reference fuel flow, temperature exponent X_{rf}	0.5
		+	table	
npower_ff	int	+	number of power required values (maximum nengtmax)	
nalt_ff	int	+	number of altitudes (maximum nengtmax)	
ntemp_ff	int	+	number of temperatures (maximum nengtmax)	
power_ff(nengtmax)	real	+	power required P_q	
alt_ff(nengtmax)	real	+	altitude h	
temp_ff(nengtmax)	real	+	temperature τ	
ff(nengtmax,nengtmax,nengtmax)	real	+	fuel flow $\dot{w}(P_q,h,\tau)$	

Chapter 75

Structure: RecipModel

Variable	Type		Description	Default
		+	Reciprocating Engine Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Engine'

engine identification: used by IDENT_engine of EngineGroup input

installed: power available P_{av}, power required P_{req}, gross jet thrust F_G, net jet thrust F_N
uninstalled: power available P_a, power required P_q, gross jet thrust F_g, net jet thrust F_n
fuel flow = specific fuel consumption * power ($\mathrm{sfc} = \dot{w}/P$); mass flow = fuel flow / fuel-air ratio

reciprocating engine model can be used by more than one engine group, so all parameters fixed

Variable	Type		Description	Default
kRecipModel	int		reciprocating engine model number	
		+	Weight	
MODEL_weight	int	+	model (0 fixed, 1 $W(P)$)	1
Weng	real	+	engine weight (fixed)	0.
		+	engine weight, W_{eng} vs P_{eng} model ($W = K_{0\mathrm{eng}} + K_{1\mathrm{eng}}P + K_{2\mathrm{eng}}P^{X_{\mathrm{eng}}}$)	
Kwt0_eng	real	+	constant $K_{0\mathrm{eng}}$	0.
Kwt1_eng	real	+	constant $K_{1\mathrm{eng}}$	0.25
Kwt2_eng	real	+	constant $K_{2\mathrm{eng}}$	0.
Xwt_eng	real	+	exponent X_{eng}	0.
		+	Custom Weight Model	
WtParam_recip(8)	real	+	parameters	0.

		+	Parameters	
		+	Engine Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	1000.
sfc0_ref(nratemax)	real	+	specific fuel consumption (sfc_0)	0.60
F0_ref(nratemax)	real	+	fuel-air ratio (F_0)	0.08
SF0_ref(nratemax)	real	+	specific jet thrust ($F_g = SF_0\dot{m}$)	0.
Pmep_ref(nratemax)	real	+	mean effective pressure limit (P_{mep})	1000.
Pcrit_ref(nratemax)	real	+	critical (throttle) limit (P_{crit})	1000.
N0_ref(nratemax)	real	+	reference engine speed (N_0)	2000.
Nspec_ref	real	+	specification engine speed (N_{spec})	2000.
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	
rN0(nratemax)	real		reference engine speed (N_{0R}/N_{spec})	
rcrit(nratemax)	real		critical power ($P_{\mathrm{crit}R}/P_{0R}$)	
rmep(nratemax)	real		mechanical limit of power ($P_{\mathrm{mech}R}/P_{0R} * N_{\mathrm{spec}}/N_{0R}$)	

Reference Engine Rating: SLS, static
    if MCP scaled, ratios to MCP values kept constant
engine rating: match rating designation in FltState; typically designated as
    'MRP' = Maximum Rated Power (5 or 10 min)
    'MCP' = Maximum Continuous Power (normal operations)
ratings encompass mixture settings and supercharger speeds

Pmep_ref: zero for no mechanical (mep) limit
Pcrit_ref: zero for no critical (throttle) limit; Xcrit = 0. for limit independent of engine speed

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		+	Scaling	
FIX_size	int	+	engine size (0 scaled, 1 fixed)	0
Xo	real	+	specific output exponent X_o	0.2
Xs	real	+	mean piston speed exponent X_s	0.3
Xf	real	+	specific fuel consumption exponent X_f	0.1
Ksfc1	real	+	specific fuel consumption constant K_{sfc1}	1.
Ksfc2	real	+	specific fuel consumption constant K_{sfc2}	0.
KN1	real	+	engine speed constant $K_{N\text{spec1}}$	1.
KN2	real	+	engine speed constant $K_{N\text{spec2}}$	0.
			Derived scaling	
Xsfc	real		exponent $-X_f/(2-X_o)$	
XN	real		exponent $-(1+X_s)/(2-X_o)$	
		+	Power Available	
MODEL_Pav	int	+	model (0 constant P_a)	1
Kp(nratemax)	real	+	factor K_p	1.
Kram(nratemax)	real	+	constant K_{ram}	1.
XpN(nratemax)	real	+	exponent X_{pN}	1.
Xpt(nratemax)	real	+	exponent $X_{p\theta}$	0.5
Xcrit(nratemax)	real	+	exponent X_{crit}	3.0
		+	Performance at Power Required	
		+	fuel flow, $\dot{w}_{req}/\dot{w}_0$ vs P_q/P_0	
MODEL_Kffq	int	+	model (1 polynomial, 2 piecewise linear)	1
		+	polynomial	
Kffq0(nratemax)	real	+	constant K_{ffq0}	0.
Kffq1(nratemax)	real	+	constant K_{ffq1}	1.
Kffq2(nratemax)	real	+	constant K_{ffq2}	0.
Kffq3(nratemax)	real	+	constant K_{ffq3}	0.
		+	piecewise linear	
Nffq(nratemax)	int	+	number of values (maximum nengrmax)	0
Pffq(nengrmax,nratemax)	real	+	power ratio P_q/P_0	
Kffq(nengrmax,nratemax)	real	+	factor K_{ffq}	
Xffq(nratemax)	real	+	exponent X_{ffq}	0.
Xffs(nratemax)	real	+	exponent $X_{ff\sigma}$	0.

		+	fuel-air ratio, F_{req}/F_0 vs P_q/P_0	
MODEL_KFq	int	+	model (1 polynomial, 2 piecewise linear)	1
		+	polynomial	
KFq0(nratemax)	real	+	constant K_{Fq0}	1.
KFq1(nratemax)	real	+	constant K_{Fq1}	0.
KFq2(nratemax)	real	+	constant K_{Fq2}	0.
KFq3(nratemax)	real	+	constant K_{Fq3}	0.
		+	piecewise linear	
NFq(nratemax)	int	+	number of values (maximum nengrmax)	0
PFq(nengrmax,nratemax)	real	+	power ratio P_q/P_0	
KFq(nengrmax,nratemax)	real	+	factor K_{Fq}	
XFq(nratemax)	real	+	exponent X_{Fq}	0.
		+	installed net jet thrust, $K_{fgr} = F_G/F_g$ (installed thrust loss)	
Kfgr(nratemax)	real	+	constant K_{fgr}	1.

Simple model: constant power available (MODEL_Pav=0)
constant specific fuel consumption (defaults Kffq1=1. and Xffq=0., and Xf=0.)
constant fuel-air ratio (defaults KFq0=1. and XFq=0.)
no jet force (EngineGroup%SET_FN=0), no auxiliary air momentum drag (EngineGroup%SET_Daux=0)

Chapter 76

Structure: CompressorModel

Variable	Type		Description	Default
		+	Compressor Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Comp'

compressor identification: used by IDENT_engine of EngineGroup input

"0" = SLS static; "C" = MCP
mass flow = power / specific power ($SP = P/\dot{m}$); gross thrust = specific thrust * mass flow ($ST = T/\dot{m}$)

compressor model can be used by more than one engine group, so all parameters fixed

Variable	Type		Description	Default
kCompressorModel	int		compressor model number	
		+	Weight	
MODEL_weight	int	+	model (0 fixed, 1 $W(P)$)	1
Wcomp	real	+	compressor weight (fixed)	0.
		+	compressor weight, $W_{\rm comp}$ vs $P_{\rm eng}$ model ($W = K_{0\rm comp} + K_{1\rm comp}P + K_{2\rm comp}P^{X_{\rm comp}}$)	
Kwt0_comp	real	+	constant $K_{0\rm comp}$	0.
Kwt1_comp	real	+	constant $K_{1\rm comp}$	0.2
Kwt2_comp	real	+	constant $K_{2\rm comp}$	0.
Xwt_comp	real	+	exponent $X_{\rm comp}$	0.
		+	Custom Weight Model	
WtParam_comp(8)	real	+	parameters	0.

		+	Parameters	
		+	Compressor Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	
SP0_ref(nratemax)	real	+	specific power (SP_0)	
Pmech_ref(nratemax)	real	+	mechanical limit of power ($P_{\rm mech}$)	
SF0C_ref	real	+	specific jet thrust ($F_{g0C} = SF_{0C}\dot{m}_{0C}$)	
Nspec_ref	real	+	specification compressor speed ($N_{\rm spec}$)	
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	
rSP0(nratemax)	real		specific power (SP_{0R}/SP_{0C})	
rPmech(nratemax)	real		mechanical limit of power ($P_{{\rm mech}R}/P_{0C}$)	

Reference Compressor Rating: SLS, static
if MCP scaled, ratios to MCP values kept constant
compressor rating: match rating designation in FltState

		+	Power Available	
		+	referred specific power available, SP_a/SP_0	
Xspa	real	+	exponent X_{spa}	1.
		+	referred mass flow at power available, $\dot{m}_a/\dot{m}_0$	
Xmfa	real	+	exponent X_{mfa}	1.
		+	Performance at Power Required	
		+	referred mass flow at power required, $\dot{m}_{req}/\dot{m}_{0C}$ vs P_q/P_{0C}	
Kmfq0	real	+	constant K_{mfq0}	
Kmfq1	real	+	constant K_{mfq1}	
Kmfq2	real	+	constant K_{mfq2}	
Kmfq3	real	+	constant K_{mfq3}	
Xmfq	real	+	exponent X_{mfq}	1.

		+	gross jet thrust at power required, F_g/F_{g0C} vs P_q/P_{0C}	
Kfgq0	real	+	constant K_{fgq0}	1.
Kfgq1	real	+	constant K_{fgq1}	0.
Kfgq2	real	+	constant K_{fgq2}	0.
Kfgq3	real	+	constant K_{fgq3}	0.
Xfgq	real	+	exponent X_{fgq}	2.0
			Derived	
q(41)	real		referred power P_q/P_{0C} (0. to 4.0)	
fgq(41)	real		gross jet thrust F_g/F_{g0C}	
mfq(41)	real		referred mass flow $\dot{m}_{req}/\dot{m}_{0C}$	

Chapter 77

Structure: MotorModel

Variable	Type		Description	Default
		+	Motor Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Motor'

motor identification: used by IDENT_engine of EngineGroup input

"0" = SLS static; "C" = MCP

motor model can be used by more than one engine group, so all parameters fixed

Variable	Type		Description	Default
kMotorModel	int		motor model number	
		+	Weight	
MODEL_weight	int	+	NASA model (0 fixed, 1 $W(P)$, 2 $W(Q)$)	2
Wmotor	real	+	motor weight (fixed)	0.
		+	motor weight, $W_{\rm motor}$ vs $P_{\rm eng}$ model ($W = K_{0\rm motor} + K_{1\rm motor}P + K_{2\rm motor}P^{X_{\rm motor}}Q^{X_{q\rm motor}}S^{X_{s\rm motor}}$)	
Kwt0_motor	real	+	constant $K_{0\rm motor}$	0.
Kwt1_motor	real	+	constant $K_{1\rm motor}$	0.
Kwt2_motor	real	+	constant $K_{2\rm motor}$	0.
Xwt_motor	real	+	exponent $X_{\rm motor}$	0.
Xwtq_motor	real	+	exponent $X_{q\rm motor}$	0.
Xwts_motor	real	+	exponent $X_{s\rm motor}$	0.
		+	motor weight, $W_{\rm motor}$ vs $Q_{\rm peak}$ model	
KIND_design	int	+	torque-to-weight design (0 only high Q/W; 1 high Q/W, 2 low Q/W factor)	0

		+	controller weight ($\Delta W = K_{\rm ESC} P^{X_{\rm ESC}}$)	
Kwt_ESC	real	+	constant $K_{\rm ESC}$	0.
Xwt_ESC	real	+	exponent $X_{\rm ESC}$	0.
		+	Custom Weight Model	
WtParam_motor(8)	real	+	parameters	0.
		+	Parameters	
		+	Motor Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	0.
Ppeak_ref(nratemax)	real	+	mechanical limit of power ($P_{\rm peak}$)	
Nspec_ref	real	+	specification motor speed ($N_{\rm spec}$)	
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	
rPpeak(nratemax)	real		mechanical limit of power ($P_{{\rm peak}R}/P_{0C}$)	

Reference Motor Rating: SLS, static
if MCP scaled, ratios to MCP values kept constant
motor rating: match rating designation in FltState

		+	Performance	
		+	Motor/Generator Efficiency	
KIND_eff	int	+	kind (1 fixed, 2 function power, 3 map)	2
		+	fixed or function power	
eta_motor	real	+	reference efficiency (at $P_{\rm eng}$)	1.00
loss_motor	real	+	power loss (fraction $P_{\rm eng}$)	0.00
		+	efficiency map ($P_{\rm loss} = P_{\rm eng} f_{\rm loss} \sum_{i=0}^{3} \sum_{j=0}^{3} C_{ij} t^i n^j$)	
Closs(4,4)	real	+	loss coefficients Closs(i+1,j+1)= C_{ij}	0.00
floss	real	+	factor $f_{\rm loss}$	1.00
eta_cont	real	+	controller efficiency	1.00

		+	Scaling	
KNspec	real	+	specification motor speed variation (K_{Ns})	0.
KNbase	real	+	base motor speed variation (K_{Nb})	0.

N_{spec} used by efficiency map; N_{base} affects P_{peak} scaling
for no variation of motor speeds with scale, use KNspec = KNbase = 0.

		+	Thermal Management System	
		+	mass flow (lb/sec or kg/sec) from rejected heat (hp or kW)	
KTMSm0	real	+	constant $K_{\text{TMS}m0}$	0.
KTMSm1	real	+	constant $K_{\text{TMS}m1}$	0.07
XTMSm	real	+	exponent $X_{\text{TMS}m}$	1.
		+	power (hp or kW) from mass flow (lb/sec or kg/sec)	
KTMSp0	real	+	constant $K_{\text{TMS}p0}$	0.
KTMSp1	real	+	constant $K_{\text{TMS}p1}$	0.6
XTMSp	real	+	exponent $X_{\text{TMS}p}$	1.
		+	gross jet force (lb or N) from mass flow (lb/sec or kg/sec)	
KTMSf0	real	+	constant $K_{\text{TMS}f0}$	0.
KTMSf1	real	+	constant $K_{\text{TMS}f1}$	6.0
XTMSf	real	+	exponent $X_{\text{TMS}f}$	1.
		+	weight (lb or kg)	
KTMSw0	real	+	constant $K_{\text{TMS}w0}$	4.0
KTMSw1	real	+	constant $K_{\text{TMS}w1}$	0.3
XTMSwp	real	+	exponent $X_{\text{TMS}wp}$	1.
XTMSwm	real	+	exponent $X_{\text{TMS}wm}$	0.

Chapter 78

Structure: JetModel

Variable	Type		Description	Default
		+	Jet Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Jet'

---

jet identification: used by IDENT_jet of JetGroup input

installed: thrust available T_{av}, thrust required T_{req}
uninstalled: thrust available T_a, thrust required T_q
"0" = SLS static; "C" = MCT
mass flow = thrust / specific thrust ($ST = T/\dot{m}$); fuel flow = specific fuel consumption * thrust ($\text{sfc} = \dot{w}/T$)

jet model can be used by more than one jet group, so all parameters fixed

as model for reaction drive of convertible engine:
only use sfc0C_ref and parameters for thrust available and performance at thrust required
T0_ref and ST0_ref required, but not used; weight, ratings, technology, and scaling variables not used

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Variable	Type		Description	Default
kJetModel	int		jet model number	
		+	Weight	
MODEL_weight	int	+	RPJEM model (0 fixed, 1 $W(T)$)	1
Wjet	real	+	jet weight (fixed)	0.
		+	jet weight, W_{jet} vs T_{jet} model ($W = K_{0\text{jet}} + K_{1\text{jet}}T + K_{2\text{jet}}T^{X_{\text{jet}}}$)	
Kwt0_jet	real	+	constant $K_{0\text{jet}}$	0.
Kwt1_jet	real	+	constant $K_{1\text{jet}}$	0.2
Kwt2_jet	real	+	constant $K_{2\text{jet}}$	0.
Xwt_jet	real	+	exponent X_{jet}	0.
		+	Custom Weight Model	
WtParam_jet(8)	real	+	parameters	0.

		+	Parameters	
		+	Jet Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCT'
krateC	int		MCT rating number	
		+	Reference	
T0_ref(nratemax)	real	+	thrust (T_0)	0.
ST0_ref(nratemax)	real	+	specific thrust (ST_0)	
Tmech_ref(nratemax)	real	+	mechanical limit of thrust ($T_{\rm mech}$)	
sfc0C_ref	real	+	specific fuel consumption at MCT (sfc_{0C})	
			Derived ratios	
rT0(nratemax)	real		thrust (T_{0R}/T_{0C})	
rST0(nratemax)	real		specific thrust (ST_{0R}/ST_{0C})	
rTmech(nratemax)	real		mechanical limit of thrust ($T_{{\rm mech}R}/T_{0C}$)	

Reference Jet Rating: SLS, static
if MCT scaled, ratios to MCT values kept constant
jet rating: match rating designation in FltState

		+	Technology	
ST0C_tech	real	+	specific thrust at MCT $ST_{\rm tech}$ (0. for ST0_ref(MCT))	0.
sfc0C_tech	real	+	specific fuel consumption at MCT $\mathrm{sfc}_{\rm tech}$ (0. for sfc0C_ref)	0.
		+	Scaling	
FIX_size	int	+	engine size (0 scaled, 1 fixed)	0
MF_limit	real	+	mass flow at limit ST and sfc ($\dot{m}_{\rm lim}$)	0.
ST0C_limit	real	+	specific thrust limit $ST_{\rm lim}$	0.
sfc0C_limit	real	+	specific fuel consumption limit $\mathrm{sfc}_{\rm lim}$	
			Derived scaling	
			specific thrust available (SLS static, MCT), ST_{0C} vs $\dot{m}_{0C}$	
T0C_limit	real		thrust limit	
Kst0	real		K_{st0}	
Kst1	real		K_{st1}	

			specific fuel consumption (SLS static, MCT), sfc_{0C} vs $\dot m_{0C}$	
Ksfc0	real		K_{sfc0}	
Ksfc1	real		K_{sfc1}	

ST and sfc functions are defined by values ST0C_tech, sfc0C_tech, $\dot m_{\mathrm{tech}}$=T0C_ref/ST0C_tech
and limits ST0C_limit, sfc0C_limit, MF_limit
defaults ST0C_tech=ST0_ref(MCT), sfc0C_tech=sfc0C_ref
require $\dot m_{\mathrm{tech}} < \dot m_{\mathrm{lim}}$ (otherwise get ST_{0C} = ST0C_tech and sfc_{0C} = sfc0C_tech)

for no variation of ST and sfc with scale, use FIX_size=1 or MF_limit=0.

bypass	real	+	Turbofan bypass ratio (0. for turbojet)	0.
		+	Thrust Available	
		+	referred specific thrust available, ST_a/ST_0	
Xsta	real	+	exponent X_{sta}	1.
		+	referred mass flow at thrust available, $\dot m_a/\dot m_0$	
Xmfa	real	+	exponent X_{mfa}	1.
		+	Performance at Thrust Required	
		+	referred fuel flow at thrust required, $\dot w_{req}/\dot w_{0C}$ vs T_q/T_{0C}	
Kffq0	real	+	constant K_{ffq0}	0.
Kffq1	real	+	constant K_{ffq1}	1.
Kffq2	real	+	constant K_{ffq2}	0.
Kffq3	real	+	constant K_{ffq3}	0.
Xffq	real	+	exponent X_{ffq}	1.
		+	referred mass flow at thrust required, $\dot m_{req}/\dot m_{0C}$ vs T_q/T_{0C}	
Kmfq0	real	+	constant K_{mfq0}	0.
Kmfq1	real	+	constant K_{mfq1}	1.
Kmfq2	real	+	constant K_{mfq2}	0.
Kmfq3	real	+	constant K_{mfq3}	0.
Xmfq	real	+	exponent X_{mfq}	1.
			Derived	
t(41)	real		referred thrust T_q/T_{0C} (0. to 4.0)	
mfq(41)	real		referred mass flow $\dot m_{req}/\dot m_{0C}$	

Chapter 79

Structure: FuelCellModel

Variable	Type		Description	Default
		+	Fuel Cell Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Cell'

fuel cell identification: used by IDENT_charge of ChargerGroup input

"0" = SLS static; "C" = MCP

fuel cell model can be used by more than one charger group, so all parameters fixed

Variable	Type		Description	Default
kFuelCellModel	int		fuel cell model number	
		+	Weight	
MODEL_weight	int	+	model (0 fixed, 1 $W(P)$)	1
Wcell	real	+	fuel cell weight (fixed)	0.
		+	fuel cell weight, W_{cell} vs P_{chrg} model ($W = K_{0\text{cell}} + K_{1\text{cell}}P + K_{2\text{cell}}P^{X_{\text{cell}}}$)	
Kwt0_cell	real	+	constant $K_{0\text{cell}}$	0.
Kwt1_cell	real	+	constant $K_{1\text{cell}}$	0.
Kwt2_cell	real	+	constant $K_{2\text{cell}}$	0.
Xwt_cell	real	+	exponent X_{cell}	0.
		+	Custom Weight Model	
WtParam_fuelcell(8)	real	+	parameters	0.

		+	Parameters	
		+	Fuel Cell Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	
		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	0.
sfc0C_ref	real	+	specific fuel consumption at MCP (sfc_{0C})	0.
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	

Reference Fuel Cell Rating: SLS, static
if MCP scaled, ratios to MCP values kept constant
fuel cell rating: match rating designation in FltState

		+	Performance	
idesign	real	+	design current density i_d	
pi_comp	real	+	compressor pressure ratio π_C	
		+	cell characteristics (at cell pressure $\delta_c = 1$)	
ncell	int	+	number of values (maximum nengcmax)	1
icell(nengcmax)	real	+	current density i_c	1.
vcell(nengcmax)	real	+	voltage v_c	1.
Xfc	real	+	pressure scaling exponent X_{fc}	0.38
Kmf	real	+	mass flow ratio ($\dot{m}/\dot{w}$)	86.
			Derived	
vdesign	real		design voltage v_d	
pdesign	real		design power density p_d	
vmax	real		voltage for maximum power $v_{\max}$	
irate(nratemax)	real		rated current density i_R	

reference sfc corresponds to fuel specific energy and design cell current, including technology impact
units of idesign and icell must be consistent

icell values unique and sequential; icell(1)=0.
vcell monotonically decreasing (reversed vcell unique and sequential)

simple model: define power P0_ref and specific fuel consumption sfc0C_ref, mass flow from Kmf
ncell=1 for constant v_c, hence constant efficiency, constant power and sfc (idesign, pi_comp, Xfc not used)

Chapter 80

Structure: SolarCellModel

Variable	Type		Description	Default
		+	Solar Cell Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Cell'

solar cell identification: used by IDENT_charge of ChargerGroup input

"0" = SLS static; "C" = MCP

solar cell model can be used by more than one charge group, so all parameters fixed

Variable	Type		Description	Default
kSolarCellModel	int		solar cell model number	
		+	Weight	
MODEL_weight	int	+	model (0 fixed, 1 $W(A)$)	1
Wsolar	real	+	solar cell weight (fixed)	0.
ssolar	real	+	weight density (kg/m^2)	
		+	Custom Weight Model	
WtParam_solarcell(8)	real	+	parameters	0.
		+	Parameters	
		+	Solar Cell Ratings	
nrate	int	+	number of ratings (maximum nratemax)	1
rating(nratemax)	c*12	+	rating designations	'MCP'
krateC	int		MCP rating number	

		+	Reference	
P0_ref(nratemax)	real	+	power (P_0)	0.
			Derived ratios	
rP0(nratemax)	real		power (P_{0R}/P_{0C})	

Reference Solar Cell Rating: SLS, static
if MCP scaled, ratios to MCP values kept constant
solar cell rating: match rating designation in FltState

		+	Performance	
esolar	real	+	power density (W/m^2)	
		+	Efficiency	
KIND_eff	int	+	kind (1 fixed, 2 function power)	2
eta_cell	real	+	reference efficiency (at $P_{\rm chrg}$)	1.00
loss_cell	real	+	power loss (fraction $P_{\rm chrg}$)	0.00

simple model: power density esolar and weight density ssolar; with efficiency in esolar (KIND_eff=1 and eta_cell=1.)

Chapter 81

Structure: BatteryModel

Variable	Type		Description	Default
		+	Battery Model	
title	c*100	+	title	'Default'
notes	c*1000	+	notes	
ident	c*16	+	identification	'Battery'

battery identification: used by IDENT_battery of FuelTank input

battery model can be used by more than one fuel tank system, so all parameters fixed

Variable	Type		Description	Default
kBatteryModel	int		battery model number	
		+	Performance	
MODEL_battery	int	+	model (1 equivalent circuit, 2 lithium-ion)	1
Vref	real	+	reference voltage V_{ref}	4.2
xmbd	real	+	maximum burst discharge current x_{mbd} (1/hr)	20.
xCCmax	real	+	maximum charge current $x_{CC\max}$ (1/hr)	4.
		+	actual cell depth-of-discharge ($d_{\text{act}} = d_{\min} + (d_{\max} - d_{\min}) d_{\text{use}}$)	
DoDmin	real	+	minimum $d_{\min}$	0.0
DoDmax	real	+	maximum $d_{\max}$	0.8
			Derived performance	
CfromE	real		charge capacity C (A-hr) from usable energy capacity (MJ); $(10^6/3600)$/(DoDmax-DoDmin)/Vref	
PfromE	real		power capacity P (hp or kW) from usable energy capacity (MJ); xmdb/(DoDmax-DoDmin)/Econv_dE	

		+	Thermal Management System	
		+	mass flow (lb/sec or kg/sec) from rejected heat (hp or kW)	
KTMSm0	real	+	constant $K_{\text{TMS}m0}$	0.
KTMSm1	real	+	constant $K_{\text{TMS}m1}$	0.07
XTMSm	real	+	exponent $X_{\text{TMS}m}$	1.
		+	power (hp or kW) from mass flow (lb/sec or kg/sec)	
KTMSp0	real	+	constant $K_{\text{TMS}p0}$	0.
KTMSp1	real	+	constant $K_{\text{TMS}p1}$	0.6
XTMSp	real	+	exponent $X_{\text{TMS}p}$	1.
		+	gross jet force (lb or N) from mass flow (lb/sec or kg/sec)	
KTMSf0	real	+	constant $K_{\text{TMS}f0}$	0.
KTMSf1	real	+	constant $K_{\text{TMS}f1}$	6.0
XTMSf	real	+	exponent $X_{\text{TMS}f}$	1.
		+	weight (lb or kg)	
KTMSw0	real	+	constant $K_{\text{TMS}w0}$	4.0
KTMSw1	real	+	constant $K_{\text{TMS}w1}$	0.3
XTMSwp	real	+	exponent $X_{\text{TMS}wp}$	1.
XTMSwm	real	+	exponent $X_{\text{TMS}wm}$	0.
		+	Equivalent Circuit Model	
KIND_eff	int	+	kind (1 fixed, 2 function power)	2
		+	discharge	
eta_dischrg	real	+	reference efficiency (at P_{ref})	1.00
loss_dischrg	real	+	power loss (fraction P_{ref})	0.00
		+	charge	
eta_chrg	real	+	reference efficiency (at P_{ref})	1.00
loss_chrg	real	+	power loss (fraction P_{ref})	0.00

simple model: constant efficiencies eta_dischrg and eta_chrg (KIND_eff=1)

		+	Lithium-Ion Model	
		+	discharge	
fcrit	real	+	critical voltage factor ($F_V = f_{\rm crit}$ is capacity)	0.6
fd	real	+	nominal discharge voltage ($V_d = f_d V_{\rm ref}$)	1.0
		+	open circuit voltage ratio ($V_o = V_d F_V(d)$)	
nFV	int	+	number of points (maximum 40)	0
DoD(40)	real	+	depth-of-discharge d (fraction)	0.
FV(40)	real	+	F_V	0.
Tref	real	+	reference temperature $T_{\rm ref}$ (deg C)	20.
fTC	real	+	temperature control power loss f_{TC} (fraction component power)	0.01
		+	current influence on discharge voltage	
R	real	+	internal resistance $x_{mbd}CR/V_{\rm ref}$	0.1
kdI	real	+	depth-of-discharge $k_{dI}x_{mbd}C$	0.05
		+	temperature influence on discharge voltage	
kVT	real	+	voltage increment k_{VT}	0.005
kdT	real	+	depth-of-discharge k_{dT}	0.000005
		+	charge	
fc	real	+	nominal charge voltage ($V_c = f_c V_{\rm ref}$)	1.0
kcV	real	+	CC phase starting voltage decrement k_{cV}	0.1
ks	real	+	CV phase parameter k_σ	0.2
			Derived lithium-ion discharge	
DoDrev(40)	real		reversed DoD	
FVrev(40)	real		reversed FV	

---

open circuit voltage ratio: monotonically decreasing; default used if nFV=0
default DoD = 0.,.1,.2,.3,.4,.5,.6,.7,.8,.9,.91,.92,.93,.94,.95,.96,.97,.98,.99,1.,1.01,1.02
default FV = 1.,.97,.95,.93,.915,.90,.89,.88,.87,.85,.847,.842,.835,.826,.815,.8,.78,.75,.7,.6,.4,0.

Chapter 82

Structure: Location

Variable	Type		Description	Default
		+	Location	
		+	input	
		+	fixed (dimensional, arbitrary origin)	
FIX_geom	c*8	+	input	' '
SL	real	+	stationline	
BL	real	+	buttline	
WL	real	+	waterline	
		+	scaled (based on reference length, from reference point)	
XoL	real	+	x/L	
YoL	real	+	y/L	
ZoL	real	+	z/L	
		+	reference length	
KIND_scale	int	+	kind (0 global, 1 rotor radius, 2 wing span, 3 fuselage length)	0
kScale	int	+	identification (component number)	1

Fixed input: FIX_geom = 'x', 'y', 'z' (or combination) to override INPUT_geom=2
Geometry: Location for each component
  fixed geometry input (INPUT_geom $=$ 1): dimensional SL/BL/WL
    stationline + aft, buttline + right, waterline + up; arbitary origin; units = ft or m
  scaled geometry input (INPUT_geom $=$ 2): divided by reference length (KIND_scale, kScale)
    XoL + aft, YoL + right, ZoL + up; from reference point
    option to fix some geometry (FIX_geom in Location override INPUT_geom)
    option to specify reference length (KIND_scale in Location override global KIND_scale)
  Reference point: KIND_Ref, kRef; input dimensional XX_Ref, or position of identified component
    component reference must be fixed
  Locations can be calculated from other parameters (configuration specific)

		Derived
		input, from Aircraft%INPUT_geom and FIX_geom (1 fixed; 2 scaled)
INPUT_geom_x	int	x
INPUT_geom_y	int	y
INPUT_geom_z	int	z
		from Aircraft%INPUT_geom and FIX_geom (0 calculated, 1 fixed, 2 scaled)
FIX_x	int	x
FIX_y	int	y
FIX_z	int	z
isFixed	int	all fixed (0 not, some scaled or calculated)
		fixed (dimensional, arbitrary origin)
SLloc	real	stationline
BLloc	real	buttline
WLloc	real	waterline
		scaled (based on reference length, from reference point)
XoLloc	real	x/L
YoLloc	real	y/L
ZoLloc	real	z/L
		reference length
KIND_scale_loc	int	from Aircraft%KIND_scale and KIND_scale (1 rotor radius, 2 wing span, 3 fuselage length)
kScale_loc	int	from Aircraft%kScale and kScale (component number)
scale	real	reference length

FIX $=$ 0: x calculation depends on component/configuraton; calc SLloc and XoLloc
FIX $=$ 1: x from SLloc; calc XoLloc
FIX $=$ 2: x from XoLloc; calc SLloc

		Geometry (dimensional, body axes, relative reference point)
x	real	x (+ forward)
y	real	y (+ right)
z	real	z (+ down)

Chapter 83

Structure: Weight

Variable	Type	Description	Default
WE	real	WEIGHT EMPTY	
W_structure	real	STRUCTURE	
W_wing	real	wing group	
W_wing_basic	real	basic structure	
W_wing_secondary	real	secondary structure	
W_wing_fair	real	fairings (not RP8A)	
W_wing_fit	real	fittings (not RP8A)	
W_wing_fold	real	fold/tilt (not RP8A)	
W_wing_control	real	control surfaces	
W_rotor	real	rotor group	
W_rotor_blade	real	blade assembly	
W_rotor_hub	real	hub & hinge	
W_rotor_basic	real	basic (not RP8A)	
W_rotor_shaft	real	inter-rotor shaft (not RP8A)	
W_rotor_fair	real	fairing/spinner (not RP8A)	
W_rotor_fold	real	blade fold (not RP8A)	
W_rotor_supt	real	rotor support structure (not RP8A)	
W_rotor_duct	real	duct (not RP8A)	
W_tail	real	empennage group	
W_Htail	real	horizontal tail (not RP8A)	
W_Htail_basic	real	basic (not RP8A)	
W_Htail_fold	real	fold (not RP8A)	
W_Vtail	real	vertical tail (not RP8A)	
W_Vtail_basic	real	basic (not RP8A)	
W_Vtail_fold	real	fold (not RP8A)	
W_tailrotor	real	tail rotor (not RP8A)	
W_tr_blade	real	blades	
W_tr_hub	real	hub & hinge	

W_tr_supt	real	rotor supports
W_tr_duct	real	rotor/fan duct
W_fuselage	real	fuselage group
W_fus_basic	real	basic (not RP8A)
W_fus_wingfold	real	wing & rotor fold/retraction (not RP8A)
W_fus_tailfold	real	tail fold/tilt (not RP8A)
W_fus_mar	real	marinization (not RP8A)
W_fus_press	real	pressurization (not RP8A)
W_fus_crash	real	crashworthiness (not RP8A)
W_gear	real	alighting gear group
W_gear_basic	real	basic (not RP8A)
W_gear_retract	real	retraction (not RP8A)
W_gear_crash	real	crashworthiness (not RP8A)
W_nacelle	real	engine section or nacelle group
W_nac_engsupt	real	engine support (not RP8A)
W_nac_cowling	real	engine cowling (not RP8A)
W_nac_pylon	real	pylon support (not RP8A)
W_airind	real	air induction group
W_propulsion	real	PROPULSION GROUP
W_engsys	real	engine system
W_engine	real	engine
W_exhaust	real	exhaust system
W_acc	real	accessories (not RP8A)
W_propeller	real	propeller/fan installation
W_prop_blade	real	blades (not RP8A)
W_prop_hub	real	hub & hinge (not RP8A)
W_prop_supt	real	rotor supports (not RP8A)
W_prop_duct	real	rotor/fan duct (not RP8A)
W_fuelsys	real	fuel system
W_fuel_tank	real	tanks and support
W_fuel_plumb	real	plumbing
W_drive	real	drive system
W_drive_box	real	gear boxes
W_drive_xmsn	real	transmission drive

W_drive_rtrsft	real	rotor shaft
W_drive_brake	real	rotor brake (not RP8A)
W_drive_clutch	real	clutch (not RP8A)
W_drive_gas	real	gas drive
W_equip	real	SYSTEMS AND EQUIPMENT
W_fltcont	real	flight controls group
W_fc_cockpit	real	cockpit controls
W_fc_afcs	real	automatic flight control system
W_fc_system	real	system controls
W_fc_fw	real	fixed wing systems
W_fc_fw_nonboost	real	non-boosted (not RP8A)
W_fc_fw_mech	real	boost mechanisms (not RP8A)
W_fc_rw	real	rotary wing systems
W_fc_rw_nonboost	real	non-boosted (not RP8A)
W_fc_rw_mech	real	boost mechanisms (not RP8A)
W_fc_rw_boost	real	boosted (not RP8A)
W_fc_cv	real	conversion systems
W_fc_cv_nonboost	real	non-boosted (not RP8A)
W_fc_cv_mech	real	boost mechanisms (not RP8A)
W_auxpower	real	auxiliary power group
W_instrument	real	instruments group
W_hydraulic	real	hydraulic group
W_hyd_fw	real	fixed wing (not RP8A)
W_hyd_rw	real	rotary wing (not RP8A)
W_hyd_cv	real	conversion (not RP8A)
W_hyd_eq	real	equipment (not RP8A)
W_pneumatic	real	pneumatic group
W_electrical	real	electrical group
W_elect_aircraft	real	aircraft (not RP8A)
W_elect_deice	real	anti-icing (not RP8A)
W_avionics	real	avionics group (mission equipment)
W_arm	real	armament group
W_armprov	real	armament provisions (not RP8A)
W_armor	real	armor (not RP8A)

W_furnish	real	furnishings & equipment group
W_environ	real	environmental control group
W_deice	real	anti-icing group
W_load	real	load & handling group
W_vib	real	VIBRATION (not RP8A)
W_cont	real	CONTINGENCY
W_fixUL	real	FIXED USEFUL LOAD
W_fixUL_crew	real	crew
W_fixUL_fluid	real	fluids (oil, unusable fuel) (not RP8A)
W_fixUL_auxtank	real	auxilary fuel tanks
W_fixUL_other	real	other fixed useful load (not RP8A)
W_fixUL_equip	real	equpment increment (not RP8A)
W_fixUL_foldkit	real	folding kit (not RP8A)
W_fixUL_extkit	real	wing extension kit (not RP8A)
W_fixUL_wingkit	real	wing kit (not RP8A)
W_fixUL_otherkit	real	other kit (not RP8A)
Wpayload	real	PAYLOAD
Wfuel	real	USABLE FUEL
Wfuel_std	real	standard tanks (not RP8A)
Wfuel_aux	real	auxiliary tanks (not RP8A)
Wscaled	real	scaled weight (sum all K=3 in operating weight)
Wfixed	real	fixed weight (sum all K=2 in operating weight)
Wfeature	real	military features in empty weight
WO	real	OPERATING WEIGHT = weight empty + fixed useful load
WUL	real	USEFUL LOAD = fixed useful load + payload + usable fuel
GW	real	GROSS WEIGHT = weight empty + useful load = operating weight + payload + usable fuel

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follows SAWE RP8A Group Weight Statement, except as noted
typical only lowest elements of hierarchy specified, others obtained by summation

set status flag when define weight
can define weights (k=2 or 3) at any level, ignore child weights if not lowest level
when print weight statement, designate all fixed (ie input) quantities

usage:

set all W=K=0; put W, with K=2 or 3

then fill structure: if K=0 and some child defined/sum, then W=$\sum$(child) and K=1

addition or increment sums all elements, with status Kt of total as follows

Ka =	0	1	2	3
Kb = 0	0	1	2	3
Kb = 1	1	1	3	3
Kb = 2	2	3	2	3
Kb = 3	3	3	3	3

		Status (0 none; 1 sum of child; 2 defined, fixed (input); 3 defined, not fixed (scaled, wt eq; or composite))
KE	int	WEIGHT EMPTY
K_structure	int	STRUCTURE
K_wing	int	wing group
K_wing_basic	int	basic structure
K_wing_secondary	int	secondary structure
K_wing_fair	int	fairings (not RP8A)
K_wing_fit	int	fittings (not RP8A)
K_wing_fold	int	fold/tilt (not RP8A)
K_wing_control	int	control surfaces
K_rotor	int	rotor group
K_rotor_blade	int	blade assembly
K_rotor_hub	int	hub & hinge
K_rotor_basic	int	basic (not RP8A)
K_rotor_shaft	int	inter-rotor shaft (not RP8A)
K_rotor_fair	int	fairing/spinner (not RP8A)
K_rotor_fold	int	blade fold (not RP8A)
K_rotor_supt	int	rotor support structure (not RP8A)
K_rotor_duct	int	duct (not RP8A)
K_tail	int	empennage group
K_Htail	int	horizontal tail (not RP8A)

K_Htail_basic	int	basic (not RP8A)
K_Htail_fold	int	fold (not RP8A)
K_Vtail	int	vertical tail (not RP8A)
K_Vtail_basic	int	basic (not RP8A)
K_Vtail_fold	int	fold (not RP8A)
K_tailrotor	int	tail rotor (not RP8A)
K_tr_blade	int	blades
K_tr_hub	int	hub & hinge
K_tr_supt	int	rotor supports
K_tr_duct	int	rotor/fan duct
K_fuselage	int	fuselage group
K_fus_basic	int	basic (not RP8A)
K_fus_wingfold	int	wing & rotor fold/retraction (not RP8A)
K_fus_tailfold	int	tail fold/tilt (not RP8A)
K_fus_mar	int	marinization (not RP8A)
K_fus_press	int	pressurization (not RP8A)
K_fus_crash	int	crashworthiness (not RP8A)
K_gear	int	alighting gear group
K_gear_basic	int	basic (not RP8A)
K_gear_retract	int	retraction (not RP8A)
K_gear_crash	int	crashworthiness (not RP8A)
K_nacelle	int	engine section or nacelle group
K_nac_engsupt	int	engine support (not RP8A)
K_nac_cowling	int	engine cowling (not RP8A)
K_nac_pylon	int	pylon support (not RP8A)
K_airind	int	air induction group
K_propulsion	int	PROPULSION GROUP
K_engsys	int	engine system
K_engine	int	engine
K_exhaust	int	exhaust system
K_acc	int	accessories (not RP8A)
K_propeller	int	propeller/fan installation
K_prop_blade	int	blades (not RP8A)
K_prop_hub	int	hub & hinge (not RP8A)

K_prop_supt	int	rotor supports (not RP8A)
K_prop_duct	int	rotor/fan duct (not RP8A)
K_fuelsys	int	fuel system
K_fuel_tank	int	tanks and support
K_fuel_plumb	int	plumbing
K_drive	int	drive system
K_drive_box	int	gear boxes
K_drive_xmsn	int	transmission drive
K_drive_rtrsft	int	rotor shaft
K_drive_brake	int	rotor brake (not RP8A)
K_drive_clutch	int	clutch (not RP8A)
K_drive_gas	int	gas drive
K_equip	int	SYSTEMS AND EQUIPMENT
K_fltcont	int	flight controls group
K_fc_cockpit	int	cockpit controls
K_fc_afcs	int	automatic flight control system
K_fc_system	int	system controls
K_fc_fw	int	fixed wing systems
K_fc_fw_nonboost	int	non-boosted (not RP8A)
K_fc_fw_mech	int	boost mechanisms (not RP8A)
K_fc_rw	int	rotary wing systems
K_fc_rw_nonboost	int	non-boosted (not RP8A)
K_fc_rw_mech	int	boost mechanisms (not RP8A)
K_fc_rw_boost	int	boosted (not RP8A)
K_fc_cv	int	conversion systems
K_fc_cv_nonboost	int	non-boosted (not RP8A)
K_fc_cv_mech	int	boost mechanisms (not RP8A)
K_auxpower	int	auxiliary power group
K_instrument	int	instruments group
K_hydraulic	int	hydraulic group
K_hyd_fw	int	fixed wing (not RP8A)
K_hyd_rw	int	rotary wing (not RP8A)
K_hyd_cv	int	conversion (not RP8A)
K_hyd_eq	int	equipment (not RP8A)

K_pneumatic	int	pneumatic group
K_electrical	int	electrical group
K_elect_aircraft	int	aircraft (not RP8A)
K_elect_deice	int	anti-icing (not RP8A)
K_avionics	int	avionics group (mission equipment)
K_arm	int	armament group
K_armprov	int	armament provisions (not RP8A)
K_armor	int	armor (not RP8A)
K_furnish	int	furnishings & equipment group
K_environ	int	environmental control group
K_deice	int	anti-icing group
K_load	int	load & handling group
K_vib	int	VIBRATION (not RP8A)
K_cont	int	CONTINGENCY
K_fixUL	int	FIXED USEFUL LOAD
K_fixUL_crew	int	crew
K_fixUL_fluid	int	fluids (oil, unusable fuel) (not RP8A)
K_fixUL_auxtank	int	auxilary fuel tanks
K_fixUL_other	int	other fixed useful load (not RP8A)
K_fixUL_equip	int	equipment increment (not RP8A)
K_fixUL_foldkit	int	folding kit (not RP8A)
K_fixUL_extkit	int	wing extension kit (not RP8A)
K_fixUL_wingkit	int	wing kit (not RP8A)
K_fixUL_otherkit	int	other kit (not RP8A)
Kpayload	int	PAYLOAD
Kfuel	int	USABLE FUEL
Kfuel_std	int	standard tanks (not RP8A)
Kfuel_aux	int	auxiliary tanks (not RP8A)
KO	int	OPERATING WEIGHT = weight empty + fixed useful load
KUL	int	USEFUL LOAD = fixed useful load + payload + usable fuel
KGW	int	GROSS WEIGHT = weight empty + useful load = operating weight + payload + usable fuel