

16-18 November 2020 Online

# HABITAT SIZING TOOL

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# Habitat Sizing Tool



- The habitat sizing tool began in 2007 with reference material found in the book "Human Spaceflight: Mission Analysis and Design" [1] and has since expanded to include integrated sizing methods for every major discipline.
- Key attributes include the ability to size the outfitting for any mission using the most common pressure vessels.
- Key variables include instant output from crew size and mission length.
- Examples:
  - 1. Mars transit habitat configurations
  - 2. Lunar base module configurations



## Example 1: Mars Transit Habitat concepts







### Agency team estimate & Tool Calibration



HYBRID 2018	Description	Design Constraints / Para	ameters			Mass Breakdown	Launch Mass	Outfitted Mass
Occupies		Maximum Crew Size	4		System		(kg)	(kg)
Mass (ke)		Max Crewed Mission Duration	1,200	days	1.1	Structures	9,225	9,225
10.625		Destination	Mars 1 Sol 0	Orbit	2.0	Propulsion	1,573	1,573
879		Pressurized Volume	316.85	m <sup>3</sup>	3.0	Power	874	874
750		Systems Volume	132.90	m <sup>3</sup>	4.0	Avionics	1,621	1,621
653		Stowage Volume	99.13	m³	5.0	Thermal	2,165	2,165
469		Habitable Volume	84.81	m <sup>3</sup>	6.0	Radiation Protection		-
692		Operating Pressure	101.30	kPa	7.0	ECLSS	4,142	4,142
895		Oxygen Fraction	21.00	%	8.0	Crew Systems	3,254	3,254
173		Life Support Closure - Water	Closed		9.0	EVA	1,116	1,116
340		Life Support Closure - Air	Closed		10.0	Research	764	764
2.086		Habitat Structure	Aluminum		11.0	Robotics	943	943
1.538		Habitat Overall Length	11.50	m	Dry Mass		25,676	25,676
3,937		Habitat Diameter	7.20	m	12.0	Stowed Provisions	-	12,935
1,317		Radiation Protection	0.00	kg	13.0	Consumables		15,319
0		EVA Capability	10		14.0	Nonpropellant Fluids	70	70
0	Mars Tranist Habitat w/ Hybrid Propulsion	Crew per EVA	2		Inert Mass		70	28,324
1,988		RCS Engine Type	440, 90, 30	N	Subtotal		25,746	54,001
1,500	Description	RCS Propellant	Hydrazine, N	N2O4		Attached Payloads		
27,385	The Mars Transit Habitat is the primary crew vessel for	Power Generation	26.64	kW		Propulsion Stage		
21,223	transportation to Mars. It is designed to support a crew	Energy Storage	5.93	kW	15.0	Propellant	1,396	300
6,764	of 4 for up to 1200 days. The habitat will be launched	Keep Alive Power (uncrewed)	5.93	kW	16.0	Payload Launch Adapter	1,772	
0	interplanetary travel, requiring element docking, as well	Solar array area	242.89	m <sup>2</sup>	17.0	In-Space Stage Adapter	1,249	1,249
0	as logisitics upload. This assembly is assumed to occur at	Thermal Radiator Area	100.33	m <sup>2</sup>				
0	the Gateway station in cis-lunar space where it will be	Actual Estimated Loss of Mission	2.25%					
0	configured and returbished for multiple missions.	Average TRL	7.87				1	
0		Mass Growth Allowance (MGA)	15.54%		0.0%	Project Mgt. Reserve	.	-
55,435		Project Management Reserve (PMR)	0%		Total Gros	s Mass	30,163	55,550

Government Reference Design [2] from Agency wide Subject Matter Experts

Government Reference Design [5] from Habitat Sizing Tool



### Dry mass and operational mass comparison

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<b>FRANSIT HABITAT REFINEMENT</b>	Г	ID numbers with AES / NextSTEP	HVBRID 2018		Mass Breakdown	Launch Mass	Outfitted Mass
		standards	Orestian	System		(kg)	(kg)
DESCRIPTION		FUNCTIONAL CATEGORY	Operation Mass (kg)	1.1	Structures	9,225	9,22
			Iviass (kg)	2.0	Propulsion	1,573	1,5
	1.0		10,625	3.0	Power	874	8
	2.0		958	4.0	Avionics	1.621	1.6
	3.0	NATURAL & INDUCED ENVIRONMENTAL PROTECTION SYSTEMS	652	5.0	Thermal	2 165	2.1
	4.0 5.0		469	6.0	Radiation Protection	2,100	2,1
	5.0	POWER SYSTEMS	692	0.0		-	-
	7.0	COMMAND & DATA HANDLING (C&DH) SYSTEMS	895	7.0	ECLSS	4,142	4,14
	8.0	GUIDANCE NAVIGATION & CONTROL (GN&C) SYSTEMS	173	8.0	Crew Systems	3,254	3,2
	9.0	COMMUNICATIONS & TRACKING (C&T) SYSTEMS	340	9.0	EVA	1,116	1,1
	10.0	CREW DISPLAYS & CONTROLS	213	10.0	Research	764	7
	11.0	THERMAL CONTROL SYSTEMS (TCS)	2.086	11.0	Robotics	943	9
	12.0	ENVIRONMENTAL CONTROL SYSTEMS (ECS)	1.538	Dry Mass		25,676	25,6
	13.0	CREW/HABITATION SUPPORT SYSTEMS	3.937	12.0	Stowed Provisions	-	12.9
	14.0	EXTRAVENICULAR ACTIVITY (EVA) SUPPORT SYSTEMS	1.317	13.0	Consumables	-	15.3
Habitat with Hybrid Propulsion	15.0	IN-SITU RESOURCE ACQUISITION & CONSUMABLES PRODUCTION SYSTEMS	0	14.0	Nonpropellant Eluida	70	.0,0
	16.0	IN-SPACE MANUFACTURING & ASSEMBLY SYSTEMS	0	Inort Mass	Nonpropenant 112.35	70	20.24
The Mars Transit Habitat is the primary	17.0	MANIPULATION & MAINTENANCE SYSTEMS	1.988	inert mass		70	20,3
crew vessel for transportation to Mars.	18.0	PAYLOAD PROVISIONS (OPERATIONAL MASS)	0	Subtotal		25,746	54,0
The habitat will be launched independent	19.0	PAYLOADS & RESEARCH (OPERATIONAL MASS)	1,500		Attached Payloads		
of the propulsive element needed for		MANUFACTURER'S EMPTY MASS	27,385		Propulsion Stage		
interplanetary travel, requiring element	A-H	OPERATIONAL ITEMS - CREW ITEMS	21,223	15.0	Propellant	1 396	3
docking, as well as logisitics upload.	I-J	OPERATIONAL ITEMS - EQUIP SPARES & MAINT ITEMS	6,764	16.0	Propenant Devlaad Loup & Adapter	1,330	5
For attachment to the hybrid propulsion	K-L	OPERATIONAL ITEMS - CONSUMABLES (INCLUDING RESIDUALS)	64	10.0	Payload Lausen Adapter	1,772	4.0
element, the habitat requires solar panels	м	OPERATIONAL ITEMS - CLOSED SYSTEM FLUIDS (REPLENISHABLE)	0	17.0	In-Space Stage Adapter	1,249	1,24
and batteries for keep alive power and a	N-P	OPERATIONAL ITEMS - PYROTECHNIC/ORDNANCE ITEMS & BALLAST	0				
small transfer propulsion stage to reach	0.5	OPERATIONAL ITEMS - MULTI-PURPOSE CUNTAINERS & CARRIERS	0				
the cis-lunar orbit where it will be	Q-5	OPERATIONAL ITEMS - PROPELLANT	0				
assembled to the hybrid propulsion	1-4		28.050	0.0%	Project Mgt. Reserve	-	-
element.		GROSS MASS	55,435	<b>Total Gros</b>	s Mass	30,163	55,5

### Initial Inputs and Summary Output

	A. Inputs	5
	Crew Size	4
	Mission Duration in Days	1200
	Crew Mission Days	4800
	Extravehicular Activity (EVA)	
	Number of EVA's	10
	Crew per EVA	2
	Location (Select from List)	Mars 1 Sol Orbit
	Gravity Level (g)	0
	Max Distance from Earth (km)	402,000,000
Hobitat mass	Heliocentric Distance (AU)	2
	Min Solar Charge Time (min.)	1,077
projection curve	Max Eclipse Time (min.)	400
	Color Sturd over (M/m <sup>2</sup> )	591
	Mass Projection (kg)	41 805
	Pressurized Volume Projection (m <sup>3</sup> )	250.00
	Program Manager's Reserve	0%
	Target Mission Success	98.0%
Input impacts		
Spares mass	User Input	:
	– Numb	er of crew
	– Missic	on duration
	– EVA a	ctivity
	– Prima	ry location

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### Master Equipment List (MEL)

(Qty.)		(	N	1G	A	)										(	T	R	L	)
l Made Figher of Lief	8	Unit Mana	Radi Marr	1	160A 140	Laund Mass	Culleri Mara	3 2 2	Pasar Registration Plantfold	o ige	11 apr	z Ş	Dan dar	Hel Shanage Volume	Radjon and Values	Hel Systems Values	Pressurfield Values	T	M 74	Failurais ( Naisa
11 Brusses	1	198.87	8171.87 1704.87	TARE IN STR	1004.12 204.03	1962.80	1903.00				Tert		7.38				216.00		201	Frequer Vessel Valume
1.3 Zmanie v Ziradem bie od Ziradem	1	20132	3137	18.07%	211.21	352.08	352.18								1.00	1.00			201	20% of interact launch many
13 MOP3	1	1768.04	198.04	18.07%	20170	2028.79	2028.79							Internet distants					204	Edward Miles
18 HDB Pwts	-i -	110.11	110.13	3.07%	31.79	1008.31	1228.31												18	E sales Arres
14 CEMPwin 17 HDB I CEM Adapter	-	1.00	1.00	3.07%	1.00	1.00	1.00												1.1	
18 Western	8	118.48	236.88	3.07%.	2.11	201.00	201.00												27	
2.8 Propider 2.1 Propider Eur	1	1007-00	1007-08	B.BPL TR.DPL	208.12	1673.60	1673.60											1.1	187	
23 38 Futur		6.00	COL M	28.0PL	214.78	E.00	873.7N													
3.1 Enter Arrays 3.2 Enteries	11	#101.10 #841.14	1.00	28.07%	1.00	5.00 5.00	5.00							Internal Ruberies	6.00	1.00		8 7	1	
13 Pose Electroite		238.01	338.81	28.07%	84.70	623.81	603.81								2.00	2.00			71	
14 Call Power Plant		1.00	1.00	28.07%	101.00	605.20	885,20												1	
14 HORD Frantieris 3.7 Fuel Frantieri Tartin	11	1.00 1.00	5.00 5.00	28.07%	5.00	5.00 5.00	5.00					_						2	1	
3.8 Outline Resoluti Tartes 3.8 Marine France Units		E.M.	1.00	28.07%	1.00	1.00	1.00											2	1	
4.8 Adustos			1427.68	TARFS.	161.01	101.31	101.30	200.31	18.38						1.00	4.00				
43 Command & Data Handline	1	18.01	335.63	18.00%	d8.10	276.03	276.03								1.00	1.00		÷.	N	
43 CaladiCar mark Ceter 44 Carmaniations	3	201.00	206.00	LUPL LUPL	16.33	216.87	216.87								5.10	1.00		2	21	
4.8 between and Video	1	223.84	203.84	B.BPL B.BPL	2.84	81.80	81.80								1.00	1.00		2	27	
43 Exclam Cashallers	1	101.00	101.00	18.00% 28.00%	28.00	100	100								£10 £10	£.10 £.10		2	1	
43 Animeter Californi 14 December 201	1	207.00	207.00	28.07%	81.78	208.76	218.75	100.70	100.70						6.10	6.10		2	w	
5.1 Passing Thermal Cartest 5.2 Addas Thermal Cartest Internal	1	8128	81.20 213.34	28.07%	10.00	64.11 201.41	84.11	208.27	208.27			_			1.00	1.00		1.1	1	
1.3 Autor Termal Cartrol (Enternal)	-i -	381.28	301.20	28.07%	76.30	381.00	381.80	111.24	111.24						2.00	2.00				
6.1 Failable Protection	1	and a	6.00	* IEWIE	6.00	L	-									6.00				
5.1 Facilation Protection (at cross quarters) 7.8 ECL38			1.00	- KOVIE	1.00	L	1.0								1.00	1.00			- i -	
7.1 Admosphere Residulation Sys (ARS) 7.2 Admosphere Card & Supply System (ACS)	11	202.10	5.00 5.00	18.07%		E.00	1.00								4.00	5.00		1		
7.3 Temp & Hamidly Central (FHC) 7.4 Webs Responses & Man (WRM and Washe Managers	11	84.33	5.00	18.07%		5.00	1.00								4.00	5.00		1.1	1	
7.8 For Detection & Suppression to white an Operation \$17.3.8 Sectors		76.87	5.00	18.00%	1	1.00	1.00								1.00	5.00			1	
74 Am ECLAS		367.84	301188	HATL	F INLA	10.1	00.0	4007.88	3636.87						6.00	6.00			- ·	Easted on Onlan spee loop ECLES
7,1 Alexangherin Fondalization 335 (APCI) 7,3 Alexangherin Caril & Supply System (ACII)	3	776.83	1013.04	18.07%	203	198.89	1761.69								4.00	8.00		1.1	223	
7.3 Temp & Hamidly Cash of (HC)	1	887.23	887.23	18.02%		696.81	686.81								6.00	4.00		1	н	
7.8 For a Defendion it. Suppresentation in mildle	- i -	304.63	304.63	B.BPL		366.33	386.33								1.00	1.00			44	
Li Cresilpatera		844.64	3628.45	TAPL	11.70	1081.34	108.34								3.00	2.00			101	
83 Wardtoon	1	84.00	84.00	18.07%	12.60	81.40	81.40					_			1.00	1.00		1.1	10	
8.4 Waste and Hostern Comparison	1	201.00	201.00	11.075	38.39	264,28	284,28								6.00	4.00			33	
8.8 Cross Health Care Method	1	464.00	464.00	B.BPL	68.10	122.10	822.10								2.00	2.00			÷.	
8.7 Cross Health Care III are shed 8.8 General Provisions	1	187.65	167.60	18.0FL 18.0FL	28.16	218.76	218.74								2.00	2.00		;	21	
8.3 Mateinstein Werindalten Franz renak wir sein auf aus die 190	1	2001.00	138.00	11.075	28.28	18.28	18.28	8001.00					_		2.00	2.00		2	23	NUCL on other stream
M EVA		101.00	876.23	TAPL	148.83	1118.78	118.78	10.0							3.00				87	
12 Tals	-i -	THE	718.00	18.07%	17.28	10.25	10.28								1.00	100			77	
8.4 Zupper i Explorent	-i -	8.0	86.00	B.BPL	14.48	TILM	TILM	10.0							1.00	1.00			N	
16.1 Life Externes	1	10.00	612.00	TLOPS.	61.80	673.80	673.80	201.00							2.00	2.00		1.1		
11.3 Physical Eclement 11.3 Materials Proceeding	1	20.00	212.00	18.0F%	27.80	288.80	201.00	201.00							2.00	2.00		÷.	31	
11.4 Human Research Paulity 11.1 Materian Washington		736.63	1.00	18.00%	1.00	1.00	1.00	201.00							2.00	0.00		1 C		Unident
TER Robotis Arm. Wartstation			8.00	TAPL	8.00	6.00	1.00													Constrained
10.7 Table Robertle Way Installation 10.8 Victor of Readily Way Installation			5.00	TLOPL	1.00	1.00	1.00													Linguisma Linguisma
TLE Fainting			ILL.II	HAPL	122.00	MLM	MLM	LB												Lingstown
11.1 Lander Systems 11.2 Roser Systems		1.00	5.00 5.00	TLOPL TLOPL	1.00	E.00	1.00													
TL3 Foliadio Egulatera Sen Mana	3	CR.00	CLU THE	TAPL	123.00	843.00	80.00	17988.47			1.000	-			underers Vision of		19.00		107	Total Foreman Land Volume
U.S. Shaned Provisions			11,30.91	HATL	1,007.10		U.M.W	18.0						100.0	Grees	Systems Volume	10.0			NPC mark up applied
TL1 Personal jury or on an analysis TL2 Househeaving Expendiation jury or on simil	4	104.00	CH.00 3.848-03	TLOPL	10.40	801.40 did1.49	001.00	10.00							Grow	Showage Volume	84.01			2010, mark up analised Rest scheme Makelande Maker of
TL3 Cress system matchenance (or day)	1000	127	328.30	B.BPL	48.39	278.69	278.69	1.0												
TLE ECLES Expendition (per day)	100	1.85	1, 195, 20	H.BPL H.BPL	178.28	1214.48	13%48	1.0												
TLE ECLES Sparses (per sig) TL2 Habitat Sparses (EVA) (per sig)	1000	1.00	701.32	18.00%	263.09	2019.72 803.37	2018.73	1.00												
TLE Materianan Explanant (per day) TLE Consumation	1000	10	2,004.00	TLOPL BATS	301.40	2304.60	2354.60	1.00												
12.1 Positivel participage	4400	2.48	T1,804.00	18.00%	1,781.60	13088.40	13088.40	6.00												
12.3 Lik Support Consumation	-	E N	673.00	TLOPE.	101.00	773.80	772.80	1.00												
16.8 Non-Propellant Plaint (Ferninal Plants & California)	-	100	8.79	LIFE	1.00	0.79	8.9	10.0												
12.1 MP3		61.79 1.01	68.79 E.00	LOPL LOPL	5.00 5.00	68.79 E.00	68.79	L.00												
ner t Mans			34,638.88	HAVE	3,681.37	61.79	28,334.27	201.01				Nel Xian	age Volume	82.61						Nel Elsewage Volume uses 20kg per did CTB
			44,841,88	11.27%	708.81	28,748.28	MIN.N	1718.43										-	Mass Cr.	nth Allonance
Intel Large Propulsari		THE	THE	LOPL		1201.00	301.00	1.00												
Mid Leve Propellant 18.8 Propellant 14.1 MP3: Algoriphicat)				LOPL.		0.00	F 8.00	1.00									1		1	
Nati Lens Propulat N.R. Propulat 16.1 MP3: Algerspelant 16.3 16.3							6.00	6.00												
Said Laws Propulsed The Propulsed Sci 1 MP2 (Apropulsed) 54.3 Sci 3 Sci 3 Nat Mana Mana Kai Lawah Valaka Propulsi Asiptar	1	UMUN	dictorial United	11.07%	2,128.01	27,142.17	1.00 1.301.70 1771.60	1.00 17,761.00 8.00												
That Lass Propulset 161 Propulset 162 Propulset 163 District Control of the Control 163 District District Control of the Control 163 District District Control of the Control 173 District Control of the Control of the Control 174 District Control of the Control of the Control 175 District Control of the Control of the Control 175 District Control of the Control of	-	UNLUS UNKER	da, ser an 1, ballas 1, ballas	11.0FL 11.0FL	7,128.01 271.09 162.00	27, H2.17 1,771,68 1,348,63	1.00 14,301.70 1771.60 1241.60	17,761.03 17,761.03 1.01												

- Automatic input from all discipline tabs
- Quantity adjustments
- Technology Readiness Level (TRL) estimate
- Mass Growth Allowance (MGA) estimate
- Outputs to Summary Tab
  - Systems mass
  - Stowage mass
  - Vehicle mass
  - Average TRL
  - Average MGA
  - Equipment, Stowage, and Habitable Volumes
- Capabilities
  - Equipment and stowage volumes based on average mass density estimates for each system
  - Launch mass adjustments available for payload limits
  - Outfitted mass provided for mission requirements



# 0.0 Mission Analysis

#### User Input

#### - None

- Automatic calculations based on destination input.
- Automatic input to discipline worksheets
- Locations include:
  - Earth Surface
  - Lunar Surface
  - Mars Surface
  - Phobos Surface
  - Deimos Surface
  - Space Station Orbit
  - Earth-Moon L1
  - Earth-Moon L2

- Lunar DRO\*
- 100 km Lunar Equatorial Orbit\*
- Sun Earth L2
- 1.2 AU Typical NEA
- 500 km Mars Equatorial
- Mars Phobos Orbit
- Mars Deimos Orbit
- Mars 1 Sol Orbit

0.0 Mission Analysis								
	Orbital Body	Gravity Level	Max Distance from Earth	Heliocentric Distance	Min. Solar Charge Time	Max Edipse Time	Max Thermal View Temperature	Solar Flux Level
Location		(g)	(km)	(AU)	(minutes)	(min.)	(4)	(W/m <sup>2</sup> )
Earth's Surface	Sun	1.00	0	1	0	1440	295	1000
Lunar Surface	Earth	0.195	384,400	1	19,670	19,670	375	1395.1
Mara Surface	Sun	0.378	402,000,000	1.52	9	1477	299	321
Phobos Surface	Mars	0.0006	402,000,000	1.52	230	230	290	591
Deimos Surface	Mars	0.0003	402,000,000	1.52	909	909	290	591
Space Station Orbit	Earth	0	426	1	55	37	290	1395
Earth-Moon L1	Earth	0	322,000	1	99,999	240	290	1395
Earth-Moon L2	Earth	0	444,000	1	99,999	240	375	1395
Lunar DRO	Maan	0	444,000	1	99,999	240	375	1395
100km Lunar Equatorial	Maan	0	384,400	1	71	47	375	375
Sun Earth L2	Sun	0	1,500,000	1.01	99,999	0	375	1339
1.2 AU Typical NEA	Sun	0	332,000,000	1.2	99,999	0	375	949
500 km Mars Equatorial	Mars	0	402,000,000	1.52	80	43	290	591
Mars Phobos	Mars	0	402,000,000	1.52	339	65	290	591
Mars Deimos	Mara	0	402,000,000	1.52	369	70	290	591
Mara 1 Sol Orbit	Mara	0	402,000,000	1.52	1077	400	290	591

- Data provided includes:
  - Gravity Level (g)
  - Max. Distance from Earth (km)
  - Max. Heliocentric Distance (AU)
  - Min. Solar Charge Time (min.)
  - Maximum Eclipse Time (min.)
  - Max. Thermal View Temperature (K)
  - Solar Flux Level (W/m<sup>2</sup>)

\*Update needed to include NRO





# 2.0 Propulsion

2.0 Propulsion		Unit Mass	Basic Mass	MGA	MGA	Predicted Mass	TRL	Rationale / Notes
		(kg)	(kg)	(%)	(kg)	(kg)		
2.0 Propulsion			1,367.48	20.00%	273.50	1,640.98		
2.1 MPS		1,367.48	1,367.48	20.00%	273.50	1,640.98	8	
2.2 Reaction Control	System (RCS)		0.00	20.00%	0.00	0.00	8	
14.0 Propellant			1,395.89			1,395.89		
14.1 MPS	(bipropellant)	1,395.89	1,395.89			1,395.89		
14.2 RCS			0.00			0.00		
14.0 Non-Propellant Fluids			69.79			69.79		
14.1 MPS	(bipropellant)	69.79	69.79			69.79		
14.2 RCS			0.00			0.00		
From Inputs Summary								
Initial Mase 28 301 00	93.6 310			MDS len	326			

Propulsion System Sizing	Mars Vicinity		End:						
Mars System	Point-2-Point DVs, Dinci = 5 deg		500 km Mars; i = 0 deg	500 km Mars; i = 5 deg	Mars Phobos	Mars Deimos	Mars 1-Sol orbit; i = 0 deg	Mars 1-Sol orbit; i = 5 deg	User Define
Start:			1	2	3	4	5	6	7
500 km Mars, i = 0 deg		1		289	<u>1127</u>	<u>1662</u>	<u>1159</u>	5673	
500 km Mars, i > 0 deg		2	289		1151	1662	5673	2066	
Mars Phobos		3	1127	1151		748	791	3521	
Mars Deimos		4	1662	1662	748		635	2023	
Mars 1-Sol orbit, i = 0 deg		5	1159	5673	791	635		287	
Mars 1-Sol orbit, i > 0 deg		6	5673	2066	3521	2023	287		
User Defined		7							
			RCS		MPS		*		
Mono Prop Hydrazine Isp		:	225	sec	225	sec			
Biprop NTO/MMH Isp		:	310	sec	340	sec			
LOx/LCH4 lsp		-	335	sec	360	sec			

- Orbital transfer requirements
  - TLI to NRO
  - Mars 500 km orbit to Mars 1 Sol orbit
- Outputs
  - 2.0 Propulsion hardware mass
  - 14.0 Propellant mass
- Capabilities
  - Designed for low delta-v orbital transfers within Earth, Lunar and Mars orbits





#### User Input

#### – Solar Arrays

- Options
  - Solar Arrays
  - Fuel Cells
  - Nuclear
- Automatic power requirements from other disciplines
- Outputs
  - 3.0 Power mass including...
  - Automatic output to other disciplines
- Capabilities
  - Solar array area
  - Operational power requirements
  - Keep-alive power requirements
    - Power hardware mass
    - Wiring harness mass
    - Solar array mass
    - Fuel cell fluid mass

		Solar Array	/ Po\	wer Sizing				V	/iring	Harn	ess S	Sizing		
3.8 Power				1 1				i			-			
User Input Power Required (M) Mission Duration (Days) Habitat Length System Type (selection)	16755.93 1200 11.50 Solar Array	Ground Rules & Assumptions Design Margin (%) Bus Votage Estimate Cable Parameters	30 00% 120 Y	Intermediate Computat Power Margin Desgn Power Required Cable Power	5026.7782 21782.705 22000.532			Cable Avionics ECLSS Crew Systems Umbilical	Limit Current 1 5 15 20	Length 9.35 9.35 9.35 11,50	# Circuits 212 10 8 6	Mass 106.2879 9.0980898 14.866951 19.82362	Qty 2 2 2 2 2 2 2	Total Mass (kg 212) 18. 29. 39/
Biolast Power System Heliocentric Distance (AU) Max Eclipse Time(Min) Min Light Charge Time (Min Non-Operational Power	1.52 400.36348 1076.9925 5929.67	Solar Inseliance (Wim <sup>2</sup> ) Solar Cell Efficiency (%) Array Cell Coverage (%) Initial De-Rate(%) Yeardy Degradation (%) Max Of-Point Angle (sad) Battery Max Depth OD Discharge (%) Battery Max-Specific Energy (Mhrs / kg) Areal Solar Array Density (kg / m <sup>2</sup> ) Power Electronics MER (kg / W)	1367 25% 90% 2.50% 0.10% 50% 94 3.5 0.014	Electronics Power Loss Required Distribution Power Power During Eclipse Time Required Energy Storage (Whis Required Anay Power Required Anay Power Areal Power Density (BOL) Areal Power Density (BOL)	2200.0532 24200.586 5929.6677 41649.515 2442.4457 26643.031 119.2151 109.69379	Solar Array Area Solar Array Mass Battery Mass Power Electronics Mass Total Cable Mass	242.89 850.10 886.16 338.81 300.15	Total Estimated Avg Cable	2	9.35	336	203.32558	2	30 406.6
Fuel-Cell Powered System Required Power Duration (h	n) 1	Fuel Cell Conversion Efficiency H2 Specific Energy	<u>65%</u> 3361	Total Energy Required (Whrs) Total Reactant Mass Single PowerPlant Power Number of 16 Tanks	22000.532 6.5458293 11000.266 1	Fuel Cell PowerPlant Mass Number of PowerPlants H2 Reactant Mass O2 Reactant Mass	114,59 3.00 0.73 5.82	Power Breakdown by Subsystem Structures Propulsion Power	Power Required (W) 16755.93 0.00 0.00 0.00	Non-Op Power Required 5929.67 0.00 0.00	Heat Rejected (W) 17155.93 0.00 0.00 0.00	Data Required (Mb/S) 0.00		
H2/O2 & CH4/O2 Fuel Cell Sizing	┝	Fuel Cell Conversion Efficiency Ovel Specific Energy	0.65	12 Mass / Tank Number O2 Tanks O2 Mass / Tank Total Energy Required (Whrs) Total Reactant Mass Single PowerPlant Power	0.7273144 1 5.818515 7301699 4542.5526 5000	H2 Tank Mass(kg) H2 Tank OD(mm) O2 Tank (Do(mm) O2 Tank (Do(mm) Fuel Coll PowerPlant Mass Number of PowerPlants CH4 Reactant Mass	2.97 340.69 1.68 261.06 45.00 6.00 908.51	Avionics Thermal Radiation Protection ECLSS Crew Systems EVA Research	2689.30 1298.75 0.00 4667.88 8000.00 100.00 0.00	810.35 1298.75 0.00 3820.57 0.00 0.00	2689.30 1298.75 0.00 4667.88 8400.00 100.00 0.00			
Nuclear Powered System		Kilo	-Pov	CH4 Mass / Tank CH4 Mass / Tank Number 02 Tanks 02 Mass / Tank	2 454.25526 7 519.14887	02 Reactant Mass CH4 Tank Mass H2 Tank O(jmm) 02 Tank Mass(kg) 02 Tank OD(mm) 10kW KiloPower Unit Mass	3634.04 120.97 979.30 138.23 1019.79 1554	Stowed Provisions Consumables Non-propellant Propellant Launch Adapter	0.00 0.00 0.00 0.00 0.00		0.00 0.00 0.00 0.00 0.00			

Power Requirements from other subsystem's sheets including

- Operational power
- Keep-alive power
- Heat rejection

### 4.0 Avionics Inputs



- Select from menu of subsystem components for...
  - Guidance Navigation & Control (GN&C)
  - Command & Data Handling (C&DH)
  - Communications & Tracking (C&T)
  - Crew Displays and Controls
- Number of internal deck levels
  - Output
    - 4.0 Avionics mass
    - Power requirements
  - Capabilities
    - Mass derived from Orion, ISS, and Shuttle heritage systems
    - Quantity and type of components depends on mission definitions
      - Some quantities are automatic based on input table
      - Others are selected manually
      - Number of decks selected adds additional mass
    - Power profiling of avionics components based on major mission phases

5. Thermal



#### User Input

- In-Space or Surface System
- One-sided fixed or Two-sided deployable radiators

#### • Outputs

- 5.0 Thermal system mass
- Power requirements
- Radiator area
- Capabilities
  - Active TCS based on dual pumped fluid loops (internal/external)
    - Mass and Power sizing of internal and external TCS achieved via power scaling of a reference MEL.
    - Reference MEL taken from previous NASA MSFC ACO study, "Habitat Safe Haven Configurations Study", 2017, with mass and power numbers for loop components based on Orion TCS.
    - · Quantities for specific components can be adjusted.
  - Passive TCS (insulation, heaters)
    - Mass and Power sizing of passive TCS achieved via module surface area scaling of the above-mentioned reference MEL.
  - Radiators
    - Emitting area calculated from average Areal Heat Rejection values (W/m<sup>2</sup>) based on typical thermal environment (e.g. NEO, Lunar surface, Mars surface).
    - Mass calculation based on radiator effective areal density, which depends of radiator type: fixed or deployable, single- or dual-sided.



## 6.0 Radiation Protection

6.0 Radiation Protection									
Radiation Protection	Rule	Provide Protection?	Number of Crew	Mass per Crew Member (kg)	Total Mass Required				Notes
SPE protection rule of thumb	333 kg / crew member		4	333	1332				TM-2012-217361 "Evaluating Shielding Approaches to Reduce Space Radiation Cancer Risks," by Francis A. Cucinotta, et al.
Radiation Protection	Rule	Depth of Material Required (m)	Density of Covering (kg/m <sup>3</sup> )	Volume to be Covered (m <sup>3</sup> )	Derived Width / Length / Height (m)	Volume of Material Required (m <sup>3</sup> )	Mass of Material Required (kg)	Mass of Material Required (mt)	Notes
GCR protection rule of thumb	3m coverage in regolith for surface habitats	3	1600	316.85	6.82	1,296.00	2,073,596	2,073.60	Surface provides half of protection. Mass is usually derived from in situ materials.
	5m coverage in regolith in for space habitats	5	1600	316.85	6.82	3,025.39	4,840,616	4,840.62	
	1			1		11 777 70	44 777 747	11 777 70	Heusily provided as water or asteroid materials

- Automatic calculation based on number of crew quarters to be protected
- Optional GCR protection available
- Output
  - 6.0 Radiation Protection mass
- Capabilities
  - Solar Proton Events (SPE) assumes a polyethylene panel mass wrapped around ISS like crew quarters
  - Galactic Cosmic Rays (GCR) assumes mass of water or regolith required for either in-space or surface habitat



# 7.0 Environmental Control and Life Support System

1000	-		-	-	Date Manual	Unit Val	Total Mana	Unit Reason Manuffer	Sparses Messilizer	Tend Vol.	Unit Power	Daty Cycle	Duty Cycle	Tetal Po	
	4	Totals				_	2764.0		1120.1	4.3		_		4017.9	1
ion days	500 Dec	CO2 Terrent	COAA (Carbon Chaside Removal Recemble)	1.0	212.0	4.5	212.0	19.5	18.5	0.5	1208-0	0.5	4.3	600.0	
between remapping	21 Deva		UON Carristers	6.8	7.5	4.4	0.0	0.0	6.5	0.0					1
Ma Volume	216.46 m <sup>2</sup>	CO2 Reduction	195 Sabative	1.0	205.4	0.3	205.4	190.2	190.2	0.3	790.0	0.7	0.7	804.0	1
pressure (MPA)	101.30 MPa	Number (1) Conting	CCCA (Canmon Cabin Air Assembly)	2.0	102.0	+2	204.0	5.0	16.0	0.4	468.0	1.0	4.5	898.0	
phere Composition		Trace Caritani Gastrai	Contract System	1.0	36.0	0.2	36.0	6.1	6.1	0.2	183.0	1.0	1.0	153.0	
82	77.5	Contaminant Mentioning	Reserver all Alternageliaria Manifer	1.0	9.5		9.5	7.3	23	0.0	130.0	0.8	4.0	18.6	
02	21.76	Filmation	HEPA Filter + Borean	10.0	2.1	4.0	21.8	0.0	6.0	0.0	0.0	0.0	0.0	0.0	
~	• 5	Oxygen Dener	Oxygen Generatio Assembly	· 12	368.1	4.3	368.1	210.2	238.2	9.3	1854.4	1.0	1.8	1854.4	
000	0.%	Unive Process	ISS UPA	1.0	360.0	- 6.3	390.0	363.3	363.3	0.3	300.0	0.6		165.1	
el Cpula	,	Water Process	ISS WPA	1.0	518.0	1.3	118.0	354.5	354.5	1.8	790.0	61		75.7	ł
enal Gays GQ Buggity		Vissia Conges	intered Pyrgation Comparisonal	1.0	198.0	1.0	158.0	0.0	6.0	1.0	280.0	1.0	1.0	290.0	
Temperature	293 K	Oxygen	Oxygen Gas (kg)	32.8	1.0		32.8				0.0	1.0	1.0	0.0	
ophero Look Rate	8.001 sg/Dey		Oxygen Tankage	1.0	74.8		74.8				4.0	1.0	1.8	4.0	Ľ
feed calories/day	10 vCalOey	No open	Whrogen Gas (kg)	61.2	10		41.2				- 32-	18	10	- 88-	į.
s clubbing work			Novgen Tankage	3.0	76.8		204.4			_	290.0	1.0	1.0	840.0	ŀ
a marte meter etorage		Vision	Water Technic	191.0	10		100.0					0.0		1 11	ł
			rear tange	4.4	414		Total Restore		Dance allowing			4.8		44	ł

- Automatic inputs from number of crew and mission days
- Open vs closed loop systems are selected automatically but selection can be toggled manually
- ISS ECLSS and Advanced ECLSS options available from ES62 collaborations
- Outputs
  - 7.0 ECLSS hardware mass
  - 12.0 Stowed Provisions mass
  - 13.0 Consumables mass

- Capabilities
  - Includes water, air, food, and waste balance calculated from crew needs and habitat inputs



## 8.0 Crew Systems

- Shopping list of items based primarily on ISS systems experience including specific equipment for the...
  - Galley
  - Wardroom
  - Crew Quarters
  - Personal Hygiene Compartment
  - Crew Health Care for Medical and Exercise
  - Maintenance
- Output
  - 8.0 Crew Systems mass
- Capabilities
  - Washer / Dryer system
  - Shower
  - Custom exercise equipment

la Cri	en Systems		Qty	Unit Mass	Basic Meso
				040	Pal
8.0 C	irew System	*			
	E.1 Galley				941.64
	6.1.1	Support structure and anclasures	1	157,44	157.44
	812	Food warner / monowave	2	58.10	116.20
	0.1.3	Visiar dispansar system Trank concentry		15.00	15.00
	0.1.4	Miss. Sod own we instead		190.00	10.00
	814	Frank		405.00	406.00
	55.8.8	Filmen			
	8.2 Wardro	era			54.00
	82.1	Support struct and enclosure	1	14.00	14.00
	822	Meeting/diving table	1	40.05	40.00
	0.2.3	Cney Restraints (table)	4	2.50	10.00
	82.4	Lights and Utilities	1	20.00	20.00
	8.3 Craw G	uartene			48.00
	8.3.1	Support Structure, enclosure, accustio insulation	1	30.00	30.00
	0.3.2	Lights and Utilities	1	10.05	10.00
	8.3.3	0-g Sleep Restnant (structure and restnant)	1	8.00	8.00
	8.3.4	Bunk (planelary)	0	15.00	0.00
	8.4 Person	al Wasts and Hygiene Compartment			255.90
	84.1	Support shrutt and enclosure	2	50.05	100.00
	8.4.2	Unine collection (collection device)	1	9.40	9.40
	8.4.3	Weste Management System (commode)	1	75.60	75.60
	844	Restraints	1	11.00	11.00
	8.4.5	Lighting/ventilation fixtures	2	15.00	30.00
	8.4.6	Hand/lace wash	2	15.00	30.00
	0.4.7	Shaww			0.00
		8.4.7.1 Support struct and enclosure	0	90.00	0.00
		8.4.7.2 Lighting/vertilation fotures	0	15.00	0.00
		8.4.7.5 Shower head and controls	0	3.00	0.00
	#5 Clother	Maktemate			0.00
	85.1	Wester		100.00	0.00
	853	Down	ő	60.05	0.00
	853	Supples for washer	0	0.02	0.00
	6.6 Crow H	ealth Care (Medical)			454.00
	5.5.1	Medical/surgical/dontal	1	250.00	250.00
	8.6.2	Hedificare consumables	1	108.00	108.00
	0.6.3	Envergency Breathing Apparatus	4	4.00	15.00
	5.5.4	Survival Kit	4	20.00	80.00
	8.6.5	Convenience Medication Pack	1	2.55	2.50
	0.5.6	Onal Medication Pack	1	2.70	2.70
	8.6.7	Topicel / Injectable Medication Peek	1	3.40	3.40
	8.6.4	Medical Supply Pack	1	2.95	2.90
	8.6.9	Minor Treatment Pack	1	3.90	3.90
	8.6.10	Medical Diagnostic Pack	1	4.00	4.00
	0.0.11	IV Supply Pack	1	6.23	6.20
	8.8.12	Physician Equipment Pack		2.60	2.50
	8.6.13	Energency Medical Treatment Pack	1	2.80	2.80
	8.7 Grave H	ealth Care (Exercise)			\$76.31
	67.1	TVIS Treadmill with alive loading (0-10 mph)	0	312.47	0.00
	822	T2 Treatmill with burger (3-12 meh)	0	7007.00	0.00
	87.3	CEVS Ricycle Ersoneter	ő	102.96	0.00
	8.7.4	ARED Resistive	1	544,31	944.31



# 9.0 Extra-Vehicular Activity (EVA)

NI Estrand Josén Act	way (SWN)	œy	Unit Mass	Danis Mana	NSA.	MAA	Predicted Mass	181.	Factoriale   Nation
			1748	954	0.0	148	(46)		
NO ENCL	-			476.36		18.36	40.5		
K1 Spaces	fin and the second s		100.00	12.44		8.50	1.0.20		00.046
8.1.7	pro pro lovella per circi		12100	12110	195	3.68	Later		
\$12	Aporto Curran Excelator	0	96.30	0.00	10%	1.00	0.00		Vpdio 15-17
613	Paylet suit ( no hendplant)	a	194 110	0.00	195	100	0.00		Stylen suits assert an contribut
81/1	Shuttle Advanced Crew Excape Suit (IVA)	0	12.30	0.35	13%	1.00	0.08		
8.6.6	One Last Writy Stort sal		2148	2.8	35	240	227.30		USA is 13.5 Hig, Unitilizate and entitiery is 0.37 kg (SAM MEL sept 3014)
6.1.8	Exploration IGA State	0	167.65	0.35	125	1.00	0.00		
\$17	LOVG	,	7.00	7.36	ж	8.51	721	9	LaR.D Logistice Model (Dmail from Lindery Alchieon 2051) regarding LCWS "For a 'dry' LCWS, assume 78e for allarge state.") General rule: Classe until too diny
A de Marcelo						1.20	400 W		
KA TENK	Data to the stand stand stands of the		8.00	112.00		3.00	00.01		Martine standing hadron and
8.2.1	Environment and work restracts.		1400	12.05	1216	7.00	102.30		Massar gestic (estimate)
\$22	Flight installed handhalls	10	4.00	40.00	2%	1,20	41.21	. 9	Spectral configuration specific (estimate)
13 Presidys	e Systems					114	291.14		
2.0.1	Manusci Manuscienting Unit (MMO)	0	141.00	0.00	19%	1.00	0.00	8	RMU mass from Shafle Program (acciEVA suit and t2xg properant mass)
0.5.2	Salar (ISS system)	1	38.00	38.00	- 3%	1.04	30.14	- 0	Current EE system incluses propolients
6.9.2	HestSraft (Consept)	a	434.00	0.35	30%	1.00	0.00	- 10	Estimate, and Biogenerative mass
603	Recharge propelliants (enter prop. Needled	0	1.00	0.30		1.00	0.00		ingut propellante resolud in Kilogramia
1.4 Support	Pealprant			16.10		416	¥1.4		
641	Built maintenance and sixing	1	41.00	43.00	196	4.00	44.00	- 0	Estimate
642	Unalical IOL H20, pvt. camel		7.90	7.56	2%	3.52	7.73		
543	Unabled Service Sta (C2, HSO, per, co		15.00	15.00	24	3.45	15/6		
544	Unation Parel and Contrats (airtach)		4.90	4.56	34	1.14	4.84		
845	instantion funder		4.50	6.50	34	116	6.00		
245	Battery charger and charge station	1	21.00	3.0		1.00	25.31	0	One moulined, Bastery changer (55 LIB ((5.62 kg)) and power supply (55 PSA (16.80 kg)
12.4 8949 6144			1.00	19.32	_	3.00	75.75		
1241	Configuration and an	- 20	3.80	13.0		100	10.00		Left 7 London Market
LOA.1	coord rom		3.50	10.00	_	200	20.00		rain ratana sana
12.6.2	Maximum Macroney Connent	23	3.16	32		1.00	329		Per Civil MAC Helsial Reference's Tool (hersed as 25 PMA) 2015

#### User Input

- Number and type of EVA suit
- EVA equipment options include...
  - Tools
  - Free-flyer systems

#### • Outputs

- 9.0 Extra-Vehicular Activity (EVA) mass
- 13.0 EVA consumable mass
- Capabilities
  - Shopping list or primarily heritage ISS, Apollo, and Russian systems, and Orion systems
  - Automatic consumables calculation based on number of EVAs anticipated
- Airlocks included in 1.0 Structures section
  - Options include ISS, Shuttle, and custom inflatable airlocks



### 10.0 Research

	10.0 Research		
	Space Habitat Science and I	Maintenance Workstations	٩
1	Mass Breakdown Structure		
	10.0 Research		
	10.1 Life Science	s	
	10.1.1	Microscope	
	10.1.2	Molecular Analyzer (Mass Spec TOF)	
	10.1.3	Molecular Analyzer (Gas Chromatogrpah)	1
	10.1.4	Freezer	
	10.1.5	Refrigerator	1
	10.1.6	Mass Measurement Device	
	10.1.7	Specimen Centrifuge	
	10.1.8	Interface for Gas Analysis	
	10.1.9	Cell Culture System	
	10.1.10	Small Animal Research Facility (AEM Vivarium Glove Box)	
	10.1.11	Botany/Plant Biology Research	
	10.1.12	Consummables (Media; Hydroponic Nutrient Fluid; Feed; Gasses; etc)	
	10.1.13	Microbial Detection (Medical microbiology and Astrobiology)	
	10.2 Physical Sci	inces	
	10.2.1	Heavy kn Tracker	
	10.2.2	Materials and Environment	1
	10.2.3	Relativistic Gravity Experiment	
	10.3 3-D Printer v	eorketation	
1	10.3.1	3-D printer	
Ì	10.3.2	Feed stock	
Ì	10.3.3	Reputier	
Ì	10.3.4	Verification Station (structured light scanning box)	
l	10.3.5	Giove Box	
ļ	19.0.0		

#### User Input

- Select from shopping list of research equipment
- Output
  - 10.0 Research Equipment mass
- Capabilities
  - Based primarily on ISS research systems



A

### 11.0 Robotic Systems

- Custom Shuttle derived robotic arm selected
- Output
  - 11.0 Robotic systems mass
- Capabilities
  - Shuttle, ISS, and surface robotic systems options available
  - Mobility systems included for various surface mobility options

11.3 Robotic Systems	Qty	1.1 Dry Mass	1.1 Total	Collapsed Width	Deployed Width	Length / Reach	Height	Extended Height	Martian Payload Capacity	Lunar Payload Capadity	Total Capacity	Primary Fuel Type
		(kg)	(kg)	(m)	(m)	(m)	(m)	(m)	(kg)	(kg)	(kg)	
Mana Exploration Rovers (MER)	o	180	a		2.30	1.60	1.50		6.80		0	RTG
Robotic Methane Scavenger	٥		a								0	FuelOals
Curiosity Rover	٥	820	a		2.70	2.90	2.20		80.00		0	RTG
Robornaut 2	٥	180	a	0.97		1.22	0.74		54.00		0	Battery
Rabatic Manipulator Ann	o	102	٥	0.20	0.20	1.64	0.91	1.66	500.00		٥	Battery
Sterezscopic Computer Vision	٥	0.43	a	0.28		0.06	0.04				٥	Battery
Spherical (1307) Camera	٥	0.65	a	0.11		0.11	0.11				0	Battery
Fuel Transfer Boom	٥	300	a								0	Methane
HPCL, Hubitat Personnel and Cargo Lift	٥	454.00	a	1.50	1.50	1.50	8.00	8.00	250.00	250	0	Battery
ISS Space Station Remote Meripaktor System (SSRMS)	0	1,497	a		0.36	17.60						Battery
ISS Mobile Base System (MBS)	٥	1,490	0		4.50	5.70						Battery
ISS Special Purpose Deterrous Maniputator (SPDA)	o	1,862	a		0.88	3.50						Battery
Shuttle Robolic Arm	٥		0									Battery
ISS JEM Pereta Neriplator (main am)	0		a			9.90						Battery
155 JEM Parnota Manipulator	٥		0			1.90						Battery
Robotic Arm Custom. Shuttle derived.	1	410	410			17.60						Battery
Total Dry Mass	1		410									



## 12.0 Stowed Provisions

- Automatic input based on number of crew and mission days
- Output
  - 12.0 Stowed Provisions mass
- Capabilities
  - Additional options available from selection menu
  - Provisions based on ISS experience, but custom selections are available

	12.0 Stowed Previations	155 w/ Packaging	Unit Nam	Danic Vana	MOA	NGA
	Amount Branchisers		(%2)	(%0)	2	(NI)
12.8	Stowne Prevenues			11,241		
12.1	Personal (per crea member)		108.00	436.00		
12.1	1 IVA - OPERATIONAL SUPPLIES		20.00			
	12.1.1.1	OPERATIONAL SUPPLIES	25.00			
	12112	UNPTOP	2.00			
	12113	PRINTER	2.00			
12.1	2 IVA - PHOTOGRAPHIC EQUIPHED	d.	30.00			
	12121	EQUIPMENT (STILL & VIDEO GAMERAS, LENSES,	30.00			
12.1	3 INA - RECREATIONAL EQUIPMEN	r -	90.00			
	12131	RECREATION & PERSONAL STOWAGE	90.00			
13.3	Hazahasping Expendiables (per cross day)		0.82	3048-43		
12.2	1 WA - CREW HYGIENE, WASTE M	SVT. AND HOUSENEEPING SUPPLIES	0.82			
	1221.1	PERSONAL HYDEINE HT	0.01			
	12212	HYGIENE CONSUMABLES / WOS WIPES	0.25			
	12213	TOWELS	0.10			
	12214	COMMUNITY HYGIENE KIT	0.00			
	1221.5	WASTE COLLECTION - FECAL CANISTERS	0.94			
	1231.6	WASTE COLLECTION - URINE PREFILTER	0.06			
	12.2.1.7	PEGALARINE COLLECTION BAGS (CONTINGENC)	0.00			
	12.2.1.8	TRABH BACIS	0.03			
	12.2.1.9	HEALTH GARE CONSUMABLES	0.11			
	12.2.1.10	WIPES (HOUSEKEEPING)	0.05			
	12.2.1.11	VACUUM (PRIME + 2 SPARES)	0.01			
	Crew sectors (settlements (set de))		0.27	223.38		
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12.3	PLACE AND REPAIR	D CERTIFICATION FOR SET	0.27			
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		AND DEPART OF	0.00			
	0313	SOLDERING NT	0.00			
	12314	CPILLING NT	0.04			
	12.5.1.5	APTALLERATE AND SEPARATION AT	0.05			
	12317	SUPPORE BONGING KIT	0.02			
	12.5.1.8	ELECTRONICS ANALYES AND REPAIR KIT	0.01			
	12.5.1.8	COMPUTER INSPECTION, TESTING, AND REPAIR	0.00			
	12.5.1.10	CAD AND BOFTWARE WORKSTATION	0.00			
	12.5.1.11	MATERIAL HANDLING KIT	0.02			
	12.5.1.12	PRECISION HAINTENANCE KIT	0.00			
	1231.13	30 PRINTING KIT	0.02			
	12:1:14	SOFT GOODE KIT	0.02			
	2318	THERMOPLASTICS KIT	0.05			
	12.5.1.16	OUSE INTIGATION INT	0.01			
	123117	SPARES	0.01			
	12.5.1.16	NWW WATERALS	0.00	ALC: 121		
12.4	FGISS Extended on the		1.00	1095.20		
12.6	ECLER Sparse (per dec)		1.48	1763.47		
12.7	Hebbet Spenn (EVA) (per des)		0.58	701.32		
12.8	Heisterance Equipment (air dar)		1.67	2004.00		
12.9	Cargo Transfer Bag Mass (total)			0.00		
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# 13.0 Consumables

#### • User Input

 Automatic input based on number of crew and mission days

#### Output

- 13.0 Consumables mass
- Capabilities
  - Estimates based on ISS experience and outputs from 7.0 ECLSS section

	13.0 Consumables		ISS w/ Packaging (Per Chel 6/18)	U,
13.0	Consumables			
13.1	Food including packa	ging (crew days)		
13.2		Food waste collection system (per day)		
13.3		Life Support Consumables (per day)		
13	3.1	LIFE SUPPORT ITEMS AND CONSUM	VALES	
	13.3.1.1		COOKING/EATING SUPPLIES	
	13.3.1.2		H <sub>2</sub> 0	
	13.3.1.3		0,	
	13.3.1.4		N <sub>2</sub>	
	13.3.1.5		LIOH CANISTERS (30 DAYS)	



# 14.0 Spares

- Automatic input based on number of crew and mission days
- User input on Summary tab for Target Mission Success
- Output
  - 14.0 Spares mass
- Capabilities (Work in progress)
  - Higher Mission Success rates will increase number of spares and associate mass
  - Mass will vary according to number of crew, mission duration, mean time between failures, and hardware repair capabilities
  - Data is based on LaRC model from ISS experience

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### **Example 1: Mars Transit Habitat**

Description	Design Constraints / Pan	ameters			Mass Breakdown	Launch Mass	Outfitted Mass
	Maximum Crew Size	4		System		(kg)	(kg)
	Max Crewed Mission Duration	1,200	days	1.1	Structures	9,225	9,225
	Destination	Mars 1 Sol 9	5 driC	2.0	Propulsion	1,573	1,573
	Pressurized Volume	316.85	m <sup>2</sup>	3.0	Power	874	87
	Systems Volume	132.90	m <sup>3</sup>	4.0	Avionics	1,621	1,62
	Stowage Volume	99.13	m <sup>2</sup>	5.0	Thermal	2,165	2,16
	Habitable Volume	84.81	m <sup>3</sup>	6.0	Radiation Protection	-	
	Operating Pressure	101.30	kPa	7.0	ECLSS	4,142	4,14
	Oxygen Fraction	21.00	%	8.0	Crew Systems	3,254	3,25
	Life Support Closure - Water	Closed		9.0	EVA	1,116	1,11
	Life Support Closure - Air	Closed		10.0	Research	764	76
	Habitat Structure	Aluminum		11.0	Robotics	943	94
	Habitat Overall Length	11.50	m	Dry Mass		25,676	25,67
	Habitat Diameter	7.20	m	12.0	Stowed Provisions		12,93
	Radiation Protection	0.00	kg	13.0	Consumables		15,31
	EVA Capability	10		14.0	Nonpropellant Fluids	70	7
Mars Tranist Habitat w/ Hybrid Propulsion	Crew per EVA	2		Inert Mass		70	28,32
	RCS Engine Type	440, 90, 30	N	Subtotal		25,746	54,00
Description	RCS Propellant	Hydrazine, N	N204		Attached Payloads		
The Mars Transit Habitat is the primary crew vessel for	Power Generation	26.64	kW		Propulsion Stage		
transportation to Mars. It is designed to support a crew	Energy Storage	5.93	kW	15.0	Propellant	1,396	30
If 4 for up to 1200 days. The habitat will be launched independent of the procultive element needed for	Keep Alive Power (uncrewed)	5.93	kW	16.0	Payload Launch Adapter	1,772	
interplanetary travel, requiring element docking, as well	Solar array area	242.89	m²	17.0	In-Space Stage Adapter	1,249	1,24
as logisitics upload. This assembly is assumed to occur at	Thermal Radiator Area	100.33	m2				
the Gateway station in cis-kunar space where it will be configured and caluthiched for multicle minimum	Actual Estimated Loss of Mission	2.25%					
construction and reconstruction of subscript parameters.	Average TRL	7.87				1	
	Mass Growth Allowance (MGA)	15.54%		0.0%	Project Mgt. Reserve		
	Project Management Reserve (PMR)	0%		<b>Total Gros</b>	s Mass	30,163	55,55

- Transit habitat configuration options [5]
  - Government reference
  - Bigelow configuration option
  - Sierra Nevada configuration option
  - (3 other cases were run using ISS derived module)

Description	Design Constraints / Pa	rameters			Mass Breakdown	Leunch Mass	Outfitted Mass
	Maximum Crew Size	4		System		(kg)	(kg)
	Max Crewed Mission Duration	1,200	days	1.1	Structures	10,992	10,992
	Destination	Mars 1 Sol Or	st	2.0	Propulsion Bus	1,875	1,875
	Pressurized Volume	330.00	m <sup>3</sup>	3.0	Power	1,207	1,207
	Systems Volume	129.30	m <sup>3</sup>	4.0	Avionics	1,621	1,621
	Stowage Volume	99.18	m <sup>3</sup>	5.0	Thermal	1,911	1,911
	Habitable Volume	101.52	m <sup>3</sup>	6.0	Radiation Protection		-
	Operating Pressure	101.30	kPa	7.0	ECLSS	4,393	4,393
	Oxygen Fraction	21.00	%	8.0	Crew Systems	3,254	3,254
	Life Support Closure - Water	Closed		9.0	EVA	1,116	1,116
	Life Support Closure - Air	Closed		10.0	Research	764	764
	Habitat Structure	Inflatable		11.0	Robotics	943	943
	Habitat Length	13.70	m	Dry Mass		28,076	28,076
	Habitat Diameter	6.70	m	12.0	Stowed Provisions		12,935
	Radiation Protection	0.00	kg	13.0	Consumables		15,319
	EVA Capability	10		14.0	Nonpropellant Fluids	83	83
Bigelow Module w/ Hybrid Propulsion	Crew per EVA	2		Inert Mass		83	28,338
	RCS Engine Type	440, 90, 30	N	Subtotal		28,159	56,413
Description	RCS Propellant	Hydrazine, N2	04		Attached Payloads		
The Mars Transit Habitat is the primary crew vessel for	Power Generation	26.70	kW		Propulsion Stage		
transportation to Mars. It is designed to support a crew	Energy Storage	5.96	kW	15.0	Propellant	1,664	300
of 4 for up to 1200 days. The habitat will be launched independent of the normalise element needed for	Keep Alive Power (uncrewed)	5.96	kW	16.0	Payload Launch Adapter	1,937	
interplanetary travel, requiring element docking, as well	Solar array area	243.41	m <sup>2</sup>	17.0	In-Space Stage Adapter	1,304	1,304
as logisitics upload. This assembly is assumed to occur at	Thermal Radiator Area	100.51	m²				
the Gateway station in cis-lunar space where it will be configured and out-chicked for multiple missions.	Actual Estimated Loss of Mission	2.25%					
compete and recommende for manipal missions.	Average TRL	8.39					
	Mass Growth Allowance (MGA)	18.49%		0.0%	Project Mgt. Reserve		
	Project Management Reserve (PMR)	0.00%		<b>Total Gros</b>	s Mass	33,065	58,018





### Mass Comparison

#### **Government Reference**

	Mass Breakdown	Launch Mass	Outfitted Mass
System		(kg)	(kg)
1.1	Structures	9.225	9,225
2.0	Propulsion	1.573	1,573
3.0	Power	874	874
4.0	Avionics	1.621	1.621
5.0	Thermal	2,165	2,165
6.0	Radiation Protection	-	-
7.0	ECLSS	4,142	4,142
8.0	Crew Systems	3,254	3,254
9.0	EVA	1,116	1,116
10.0	Research	764	764
11.0	Robotics	943	943
Dry Mass		25,676	25,676
12.0	Stowed Provisions	-	12,935
13.0	Consumables	-	15,319
14.0	Nonpropellant Fluids	70	70
Inert Mass		70	28,324
Subtotal		25,746	54,001
	Attached Payloads		
	Propulsion Stage		
15.0	Propellant	1,396	300
16.0	Payload Launch Adapter	1,772	
17.0	In-Space Stage Adapter	1,249	1,249
0.0%	Project Mgt. Reserve	-	
Total Gros	s Mass	30,163	55,550

#### **Bigelow Derived Concept**

Mass Breakdown	Launch Mass	Outfitted Mass
	(kg)	(kg)
Structures	10,992	10,992
Propulsion Bus	1,875	1,075
Power	1,207	1,207
Avionics	1,621	1,621
Thermal	1,911	1,911
Radiation Protection	-	-
ECLSS	4,393	4,393
Crew Systems	3,254	3,254
EVA	1,116	1,116
Research	764	764
Robotics	943	943
	28,076	28,076
Stowed Provisions	-	12,935
Consumables	-	15,319
Nonpropellant Fluids	83	83
	83	28,338
	28,159	56,413
Attached Payloads		
Propulsion Stage		
Propellant	1,664	300
Payload Launch Adapter	1,937	
In-Space Stage Adapter	1,304	1,304
Project Mat Reserve		
s Mass	33.065	58.018
	Mass Breakdown Structures Propulsion Bus Power Avionics Thermal Radiation Protection ECLSS Crew Systems EVA Research Robotics Stowed Provisions Consumables Nonpropellant Fluids Attached Payloads Propulsion Stage Propellant Payload Launch Adapter In-Space Stage Adapter In-Space Stage Adapter Project Mgt. Reserve s Mass	Mass BreakdownLaunch MassStructures10,992Propulsion Bus1,875Power1,207Avionics1,621Thermal1,911Radiation Protection-ECLSS4,393Crew Systems3,254EVA1,116Research764Robotics943Consumables-Nonpropellant Fluids83328,1593,3264Propulsion Stage-Propellant1,664Payload Launch Adapter1,304In-Space Stage Adapter1,304Project Mgt. Reserve-s Mass33,065

#### Sierra Nevada Derived Concept

	Mass Breakdown	Launch Mass	Outfitted Mass
System		(kg)	(kg)
1.1	Structures	14,843	14,843
2.0	Propulsion	1,178	1,178
3.0	Power	998	998
4.0	Avionics	1,782	1,702
5.0	Thermal	1,930	1,930
6.0	Radiation Protection	-	
7.0	ECLSS	4,144	4,144
8.0	Crew Systems	3,254	3,254
9.0	EVA	1,116	1,116
10.0	Research	764	764
11.0	Robotics	943	943
Dry Mass		30,951	30,951
12.0	Stowed Provisions	-	12,935
13.0	Consumables	-	15,319
14.0	Nonpropellant Fluids	52	52
Inert Mass		52	28,307
Subtotal		31,003	59,258
	Attached Payloads		
	Propulsion Stage		
15.0	Propellant	1,045	300
16.0	Payload Launch Adapter	2,136	
17.0	In-Space Stage Adapter	1,370	1,370
0.0%	Project Mgt. Reserve	-	
Total Gross	s Mass	35,554	60,927



# **Comparisons to Government Reference**

• Primary difference was in 1.0 Structures for use of different pressure vessels



- Structures mass for inflatables went up
  - In general inflatable systems do not decrease the mass in comparison to rigid pressure vessels due to the multiple layers required for micrometeoroid shielding, deployment systems, and inflation systems

Power mass went up due primarily to larger thermal load from larger surface area for the inflatable module



- Thermal mass went down on inflatables
  - Government reference used surface mounted radiator panels that doubled as micrometeoroid shielding which increased the thermal mass and decreased the structures mass
  - Inflatable systems used 2-sided deployable radiator panels which decreased the thermal mass



### Example 2: Lunar Surface Base

- AIAA ASCEND 2020: "Concepts for Phased Development of a Lunar Surface Base" by D. Smitherman, S. Canerday, J. Perry, D. Howard
- · Initial Sizing with Tool utilized to create
  - 2-crew Operations module
  - 2-crew Laboratory module
  - Closed loop ECLSS module
  - Mobile lab (by adding mobility base)
  - Airlock module
  - Logistics module
  - Node (by adding radial ports and cupola)
- Primary differences in each module
  - Two module lengths utilized
  - Internal outfitting based on function



Lunar Surface Base Government Reference Design [6]



## Credits / References

#### **Advanced Concepts Office Team**

- David Smitherman: A. Summary & B. MEL and overall team coordination, 6.0 Environmental Protection
- Larry Kos, Leo Fabisinski, Adam Irvine: 0.0 Mission Analysis
- Jay Garcia, Justin Rowe, Mark Ibekwe: 1.0 Structures, 16.0 Payload Adapter
- Jack Chapman, Larry Kos, Quincy Beam: 2.0 Propulsion, 14.0 Non-Propellant Fluids, 15.0 Propellant
- Leo Fabisinski: 3.0 Power
- Pete Capizzo: 4.0 Avionics
- Andrew Schnell, Steven Sutherlin, Olivier Demaneuf: 5.0 Thermal
- David Tabb, Brittany Brown, Leo Fabisinski: 7.0 ECLSS & Advanced ECLSS
- Brand Griffin, David Smitherman: 8.0 Crew Systems, 9.0 EVA, 10.0 Research
- Justin Rowe, David Smitherman: 11.0 Robotic & Mechanical Systems
- Brand Griffin, David Tabb, Justin Rowe: 12.0 Stowed Provisions
- Justin Rowe, LaRC/Chel Stromgren: 13.0 Spares

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