## FINAL REPORT ON NASA/JSC CONTRACT NO. NAS9-13207

## TECHNICAL SUPPORT FOR GUIDANCE, NAVIGATION, AND CONTROL SPACE SHUTTLE PROGRAM

PERIOD: 1 November 1972 to 31 August 1974.

23 August 1974.

(NASA-CR-140231) TECHNICAL SUPPORT FOR GUIDANCE, NAVIGATION AND CONTROL SPACE SHUTTLE PROGRAM Final Report, 1 Nov. 1972 - 31 Aug. (Draper (Charles Stark) Lab., Inc.) 130 p HC \$9.50 CSCL 22B G3/31

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The Charles Stark Draper Laboratory, Inc.

Cambridge, Massachusetts 02139

## The Charles Stark Draper Laboratory, Inc.

68 Albany Street, Cambridge, Massachusetts 02139 Telephone (617) 258-

74-SD-34 Final Report 23 August 1974

National Aeronautics and Space Administration L.B. Johnson Space Center Houston, Texas 77058

Attention: R. E. Easley, BC43

Avionics Procurement Section

Contract No.: NAS9-13207

Subject: CSEL Final Report for NASA/JSC Contract NAS9-13207,

"Technical Support for Guidance, Navigation, and Control

Space Shuttle Program."

Reference: (1) Data Requirements List (DRL) Line Item No. 2 of

the Contract Statement of Work.

## Gentlemen:

Attached is the CSDL Final Report for the subject contract. This report is being submitted in accordance with reference 1 above.

This document summaries the results of the entire contract work by providing a description of the tasks conducted and a list of the reports and memos delivered to Rockwell International Corporation, Space Division in fulfillment of this contract.

These reports, memos, and the monthly progress reports constitute the documentation of the efforts expended on each of the tasks, and also include the recommendations and conclusions based on the experience and results obtained.

Any questions pertaining to the final report should be directed to the undersigned.

Very truly yours,

Norman E. Sears

CSDL Shuttle Program Director

/djm

Attachment

68 Albany Street, Cambridge, Massachusetts 02139 Telephone (617) 258-

74-SD-34

FINAL REPORT

ON

NASA/JSC CONTRACT NO. NAS9-13207

TECHNICAL SUPPORT FOR GUIDANCE,
NAVIGATION, AND CONTROL SPACE
SHUTTLE PROGRAM

PERIOD: 1 November 1972 to 31 August 1974.

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1	GNEC-3	GN&C System Functional and Perf	formance Reguir	ements		c .
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13	•					•
14	GN&C-4	Component Requirements Definiti	Lon			c
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15	GN&C-13	Orbit Navigation Using Various Sensors	С
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3			
4	GNEC-17	GN&C Operating System Software Definition	C
5			
6	GNEC-18	Summary of CSDL Analysis Programs	c
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8	GNEC-19	Passive Rendezvous Sensors Requirements Definition	C
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2	GNEC-21	IMU Derived Attitude and Attitude Rate	c

4		GN&C-22	Passive Rendezvous Sensor Requirements Definition	С
5	٠ 🕻		(Extension)	
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.7		GNEC-23	Effect of Thermal Conditioning Operation on Shuttle	С
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4		GNEC-26	Support of Intermetrics IMU PDI Test Plan Study	С
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6		GN&C-27	Entry Guidance Evaluation Study	ŕ
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8	•	GN&C-28	GNEC 6 DOF Stability Evaluation Study	c .
9				-
0		GN&C-29	One-Way Doppler Navigation Performance for	С
1	*		Various Mission Phases	
2				•
3 .		GNEC-30	Appendix to the Requirement Formulation Document (RFD)	c
4				. •
5 .		GN8C-31	GN&C System Fault Detection, Isolation and Recovery	С
6			(PDIR) Study	
7			•	
8		GN&C-32	Boost Abort-Powered Flight Guidance Phase	c
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0		GN&C-33	Software Requirements Documentation Support	С

31			*
32	GNEC-34	Deorbit Targeting	C
. <b>3</b>			
ů.	GNEC-35	Adaption of TAEM and AUTOLAND Guidance to HFT	D
5			
6	GNEC-36	Study the Feasibility of Extending TAEM to	С
7	•	130,000 ft.	
8			٠,
9	GNEC-37	Support of Powered Flight Guidance Working Group	T
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1 - ,	GN&C-38	Support of Navigation Evaluation	T
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3	PMS-1	Inflight PMS Role	Ç
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5	PMS-2	PMS/GN&C Relationship	C
6	•		
7	PMS-3	PMS Phasing Alternatives	C
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)		PMS Punction	
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2 .	PMS-5	Define a Possible Annunciation Concept	c
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. •	PHS-6	Continuation of SSTD PMS 1.1, 1.2, 2.0 and 3.0	С
-	T T		
;			
, 7		C = Completed Task	

08	
99 (	D = Discontinued, do to lack of data
0	
1	T = Terminated under this contract, subject to continuation
•	the second secon
	under Fockwell SD Purchase Order
2	
3	

1	U K :s	•
2		TASK NO. SSTD-GNEC 1
3		•
4	TITLE: ·	Review Baseline GN&C System
5	•	
6	OBJECTIVE:	Perform a review of current GNSC baseline system
7		identifying problem areas; implied constraints;
8		effects on costs, schedule and reliability.
9		Provide possible changes and additions with
10		rationale, justification or basis for same. Draw
11		on flight experience of previous operational
12		system where appropriate. Look specifically at
13		reliability, failure detection 'coverage and
14	.*	computer sizing.
15		
16	STATUS:	Completed - (Redirected under GNSC - 12 & 17)
17		
18	SD ENGINEERING	
19	CONTACT:	M. Campbell
20		
21	DI ENGINEERING	
22	CCNTACT:	N. Sears
23		
24	START/FINISH	
25	DATES:	1 November 1972 to 28 February 1973
26		

27	REPORTS AND		<i>i</i>
28	MENOS:		
29		1}	72-SD-2, dated 11 December 1972.
30			a) MIT/DL Memo, "Recent Crew Safety
31			Probability Studies," 4, December 1972.
32			
33		2)	72-SD-3, dated 12 December 1972.
34			a) Shuttle Software Memo No. 50 Rev 1,
35	•	-	"Sizing Estimates for Primary and Backup
36		-	GNEC Software," 30 November 1972.
37	•		
38		3)	72-SD-4 dated 8 December 1972.
39		:	a) DD Memo No. 715, "Dissimilar vs Similar
40			GNCS Back-up Pros and Cons Summary," 29
41			November 1972.
42		-	
43		4)	72-SD-5, dated 11 December 1972, "Status
44	•		Review of SSTD-GN&C-1."
45			
46		5)	72-SD-14, dated 28 December 1972.
47			a) DD Memo No. 709 Rev. 1, "Computer System
48			Reliability for the Shuttle," 8 December
49			1972.
50	,		•
51		6)	72-SD-15, dated 27 December 1972.
52			a) Shuttle Software Memo No. 50 Rev 2,
53			"Sizing Estimates for Primary and Backup

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		•			
54					GNEC Software," 19 December 1972.
55					•
56			7)	73-s	D-4 dated 8 January 1973.
5 <b>7</b>				a)	"Lightning Protection Study," Excerpted
58		39 .			from Task 28-S, Vol. 4.
59				b)	"Enforcement of Single Computer Type:
60					Apollo Experience," Excerpted from Task
61					28-s, Vol. 4.
52				•	
53			8)	73-s	D-10 dated 6 February 1973.
54	,	·		a)	"Dedicated Wire vs Data Bus," Excerpted
65					from Task 28-S Vol. 2.
56				b)	"Redundancy Management Concepts for the
5 <b>7</b>		•			Assumed DCDS, " Excerpted from Task 28-S
8			•		Vol 4.
59		•		c)	"Improving Coverage (Error Detection and
70					Isolation) Over That Afforded by BITE,
71					Excerpted from Task 28-S Vol. 4.
72				- d}	"Built-In Tests", Excerpted from Task
73					28-S Vol. 4.
74				e}	"Consistency Tests," Excerpted from Task
75					28-S Vol. 4.
76				f)	"The Reliability Impact of Mission Abort
77					Strategies On Redundant Flight Computer
78					Systems," 1973 IEE Paper by R. Filene
79			÷		and W. Daly, December 1972.

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81			9) .	73-SD-13, dated 9 February 1973-
82	•			a) January 1973 Review Presentation
8:3	•			Material for SSTD GNEC-1.
84			-	· · · · · · · · · · · · · · · · · · ·
85		•	10) 7	73-SD-25, dated 15 Febraury 1973.
86				a) "Shuttle Avionics Computer System
87				Studies," Task 28-5 Vol. 4 December
88				1972.
89				· ·
90			11) 7	73-SD-40, dated 5 March 1973.
91		•	ā	i) E-2529, "STS Data Management System
92				Design (Task 2)," June 1970.
93		•	ì	) "AGC/SHUTTLE Studies Report," December
94				1970.
95	`			
96		1	12) 7	73-SD-41, dated 6 Narch 1973.
97			a	a) DD Memo No. 696, "The Mechanics of
98	÷ .			Bi-Phase Coding on a Data Bus," 12
99		*		September 1972.
00		•		
01		1	13) ; 7	3-SD-52, dated 20 March 1973.
02			a	) "Reconfiguration Control," Excerpted
03				from Task 28-S, Vol.4.
04			b	DD Memo No. 726 Rev. 1, "A Fault
05				Tolerant Reconfiguration Control Unit*
06				(Mod I), 9 February 1973.
07		n	. c	DD Memo No. 733 Rev. 1, "A Fault
				comp obto c + 11/20
			>	SSTD GN&C-I II/73

108			Tolerant Reconfiguration Control Unit
109	gr.		(Mod II), 23 February 1973.
110		d)	DD Memo No. 735, "A Fault Tolerant
111		•	Reconfiguration Control Unit" (Nod IIP),
112			9 March 1973.
113		e)	DD Memo No. 729 Rev. 1, "Time Varying
114		•	Coverage", 23 February 1973.
115	·	f)	DD Memo No. 737, "Reliability of Voting
116		:	Systems," 12 March 1973.
117		•	
118	•	14) 73-9	SD-60 dated 10 April 1973.
119		a)	DD Memo No. 730 Rev. 3, "Thoughts on the
120		t F	Meaning and Application of Coverage", 9
121	•		April 1973.
122		<b>b</b> )	DD Memo No. 746, "Vote with 5
123			Computers," 10 April 1973.
124			· · · · · · · · · · · · · · · · · · ·
125		15) 73-9	SD-109 dated 5 July 1973.
126		a)	"Shuttle Avionics Computer System
27			Studies (Task 28-S) Volume 5".
	· .		

1	U K :s	
2		TASK NO. SSTD-GN&C 2
3		•
4	TITLE:	Computer Compatibility Study
5		
6	OBJECTIVE:	Prepare a document describing the computer
7		executive and coding system at MIT/DL to the
8		extent required to: a) determine feasibility of
9	•	adapting MIT/DL computer programs to run on SD 360
10	•	computers and vice versa, and b) to estimate the
11		magnitude of the effort involved.
12		
13	STATUS:	Completed
14		
15	SD ENGINEERING	
16	CONTACT:	M. Campbell
17		
18	DL ENGINEERING	
19	CONTACT:	R. Russell
20 .		
21	START/FINISH	
22	DATES:	1 November 1972 to 12 December 1972
23	•	
24	REPORTS AND	
25	MEMOS:	
26		1) 72-SD-7 dated 12 December 1972.

SSTD GN&C-2 II/73

27	a) "Computer Compatibility with North
28	American Rockwell".
29	
30	2) . 73-SD-12 dated 9 February 1973.
31	a) "Transmittal of the MIT/PL MAC Compiler
32	Program".
33	
34	3) 73-SD-36 dated 26 Pebruary 1973.
35	a) "Transmittal of MIT/DL Users Guide to
36	MAC 360".
37	
38	4) 73-SD-110 dated 3 July 1973.
39	a) "Transmittal of CSDL MAC Compiler
40	Programs".
	·

	-	• •	
İ		U K :s	
2		٠	TASK NO. SSTD-GNEC 3
3	•		
4		TITLE:	GN&C System Functional and Performance
5	٠		Requirements Definition
6		·	
7		OBJECTIVE:	Perform studies and analysis to define GN&C
8			functional and performance requirements for all
9			flight phases except for those aspects which are
10			pure control functions.
11			
12	-	STATUS:	Completed
13			
14		SD ENGINEERING	
15	r .	CCNTACT:	M. Campbell
16			
17		DL ENGINEERING	
18	_	CONTACT:	G. Edmonds
19		•	
20		START/FINISH	
21		DATES:	1 November 1972 to 1 March 1973
22			•.
23		REPORTS AND	
24		MEMOS:	1
25			
26			1) 72-SD-6 dated 12 December 1972.

SSTD GN&C-3 11/73

- a) 23A STS Memo #14-70, "Modeling of Pressure-Altimeter System for Entry Navigation Studies", dated 10 June 1970.
- b) 23A STS Memo 17-70, "A VOR/DME Error Model for SSV Navigation Analysis", dated 1 July 1970.
- c) 23A STS Memo #20-70, "A Simplified Model for Propagation of Inertial Navigation Errors", dated 6 July 1970.
- d) 23A STS Memo \*22-70, "SSV Reentry Navigation Studies Using Barametric Altimeters and VOR/DME Measurements," dated 14 July 1970.
- e) 23A STS Memo #10-71, "Drag Measurements as a Possible Means of Reducing Altitude Estimations Errors During SSV Entry", dated 25 January 1971.
- f) 23A STS Memo #14-71, "Use of VelocityIndexed Feedback to Stabilize Altitude
  Estimates During Entry", dated 1 March
  1971.
  - g) 23A STS Memo #26-71, "Stabilization of the Altitude Component of the Orbiter's State-Vector Estimate During Entry", dated 9 April 1971.
  - h) 23A STS Memo #29-71, "DHE Error Models

54			Used in Entry Navigation Analysis",
55			dated 19 May 1971.
56		i)	23A STS Memo #44-71, "Entry and Landing
57			Navigation for SSV Orbiter Using IMU and
58			Precision Ranging System", dated 9
59		·	September 1971.
50		jj	23A STS Memo #49-71 Rev. 1, "Entry and
51			Landing Navigation Study for SSV Orbiter
52			Using PRS Navaids", dated 4 October
53			1971.
54	•	k)	23A STS Memo #11-72, "Entry and Terminal
65	•		Phase Navigation for SSV Orbiter Using
56			MLS as AILS and VOR/DME", dated 16
5 <b>7</b>			February 1972.
68		1)	23A STS Memo #41-72, "Navigation Errors
59	•		on Various Shuttle Approach
70	•		Trajectories", dated 14 June 1972.
71			
72	2)	72-s	D-9 dated 20 December 1972.
73			
74		a)	MAC Program Used to Compute TPS Weight
75			dated 19 December 1972.
76	•	b)	23A STS Memo #62-72, "Insertion Errors
77			for SSV Orbiter On Once-Around SPO
78			Trajectory", dated '11 December 1972.
79		c)	23A STS Memo #64-72, "INU Error
30			Sensitivities for Normal Entry from 270

81	•		n. mi. Earth Orbit", dated 19 December
82	· ·		1972.
83			
84		3) 72	-SD-11 dated 21 December 1972.
85			
86		a)	23A STS Memo #24-70, "Report on Orbit
87	·		Navigation Studies for SSV", dated July
88	· ·		1970.
89		b)	Memo from G. Muller (MIT/DL) to D.
90	•		Engels (NR) dated 20 December 1972.
91	•	•	
92		4) 72	-SD-16 dated 28 December 1972.
93			
94		a)	23A STS Memo #52-72, "Shuttle UV Horizon
95			Sensing Orbit Navigation Performance
96	·	*	Part I: Effect of W Matrix
97			Reinitialization Frequency and Values",
98	• .		dated 13 November 1972.
99		b)	23A STS Memo #60-72 "Shuttle UV Horizon
00			Sensing Orbit Navigation Performance
01	:		Part II: Horizon Sighting Direction and
02			Frequency Requirements", dated 15
03			December 1972.
04	•	c)	Space Shuttle GN&C Equation Document
05			#21, "Shuttle 'Unified Navigation
06			Filter", dated 21 November 1972.
^=			

108	5)	72-SD-17 dated 29 December 1972.
109		a) Memo from G. Muller MIT/DL to M. Hadden
110		(NR) dated 28 December 1972.
111		
112	6)	72-SD-18 dated 29 December 1972.
113		
114		a) 23A STS Memo #67-72, "Covariance of
115		Deviation in Flight Path Angle at Entry
116		Interface", dated 22 December 1972.
117		
118	7)	73-SD-2 dated 2 February 1973.
119	•	
120	•	a) 23A STS Memo #3-73, "Covariance Matrix
121		for IMU Alignment Errors and Correlation
122	4	Matrix between Alignment and State
123		Vector Estimation Errors", dated 3
124		January 1973.
125		
126	8)	73-SD-11 dated 8 Pebruary 1973.
127		a) MIT/DL Memo, "Once-Around SPO Trajectory
128		Data for NR", dated 6 February 1973.
129		
130	9)	73-SD-14 dated 2 February 1973.
131		a) Transmittal of "January 1973 Review
132		Presentation Material for SSTD
133		GNEC-3,487."

•		
135	10)	73-SD-20 dated 2 February 1973.
136		a) 23A STS Nemo No. 68-72, "W-Matrix
137		Propagation Using an Approximate Driving
138		Noise Model", dated 2 January 1973.
139		
140	11)	73-SD-21 dated 9 February 1973.
141	÷	a) 23A STS Memo No. 5-73, "ILS Error Model
142		for Shuttle Approach and Landing
143		Navigation Studies," dated 18 January
14.4		1973.
145		•
146	12)	73-SD-23 dated 13 February 1973.
147		a) 23A STS Memo No. 60-72, "Shuttle UV
148		Horizon Sensing Orbit' Navigation
149		Performance Part II: Horizon Sighting
150	. ,	Direction and Frequency Requirements,"
		47

1	U K :s	
2		TASK NO. SSTD-GNEC 4
3		
4	TITLE:	Component Requirements Definition
5		
6	OBJECTIVE:	Perform Studies and Analysis to determine
7		functional and performance requirements, alignment
8	·	tolerances, and acceptable error budgets for all
9		components of the GNEC system for all flight
10 .	•	phases.
11		
12	STATUS:	Complete
13	•	
14	SD ENGINEERING	
15	CONTACT:	M. Campbell
16		
17	DL ENGINEERING	
18	CONTACT:	N Sears
19		
20	START/FINISH	
21	DATES:	8 December 1972 to 1 March 1973
22		
23	REPORTS AND	
24	MEMOS:	•
25		SSTD GNEC-3,-48-7 were conducted together since
26-		the objectives were interdependent and
	•	

SSTD GN&C-4 11/73

required common simulation and analytical effort. The summary of the reports and memos issued for GN&C-3,-4&-7 are listed under SSTD GN&C-3 only.

1	. 0 K :s	
2 '	•	TASK NO. SSTD-GNEC 5
3		
4	TITLE:	Review of Mission Requirements
5	•	
6	OBJECTIVE:	Review, critique and update mission requirements
7	n	documentation supplied by SD to determine
8		adequacy, accuracy and depth of coverage.
9		Identify the critical missions which strongly
10 .		influence design.
11		
12	STATUS:	Complete
13		
14	SD ENGINEERING	
15	CONTACT:	M. Campbell
16		
17	DI ENGINEERING	·
18	CONTACT:	N. Sears
19		
20	START/FINISH	
21	DATES:	10 November 1972 to 1 February 1973
22		
23	REPORTS AND	
24	MEMOS:	
25		1) 72-SD-13 dated 27 December 1972.
26		a) DG Memo No. 1812, "Review and Comments
		SSTD GN&C-5 11/73

21				Ou war . Desidn wetelence mission	Duca
28				Book', dated 22 December 1972.	
29			b)	DG Memo No. 1813, "Review	of
30	•			Preliminary Mission Planning Guidel	ines
31				and Constraints, dated 26 Dece	mber
32				1972.	
33		•			
34		2)	73-3	D-15 dated 9 February 1973.	• • •
35			a)	Transmittal of January 1973 Presenta	tion
36				Material for SSTD GN&C-5.	

1	U K :s	
2		TASK NO. SSTD-GN&C 6
3		
4	TITLE:	GNSC Development Plan
5	•	
6	OBJECTIVE:	Prepare a preliminary GNSC Development Plan in
7	•	several levels of detail showing the GN&C
8		development efforts required to Critical Design
9		Review including start and completion date and
10 .		brief task descriptions. Exclude those aspects
11		which are pure control functions.
12		
13	STATUS:	Complete
14		
15	SD ENGINEERING	
16	CONTACT:	M. Campbell
17		
18	DL ENGINEERING	
19	CONTACT:	N. Sears
20		
21	START/FINISH	
22	CATES:	10 November 1972 to 23 February 1973
23	,	
24	FEFORTS AND	
25	memos:	
26		1) 73-SD-7 dated 15 January 1973.
		SSTD GN&C-6 11/73

27		a)	MIT/DL Memo, "List of Documents Used On
28	, <b>4</b>		Apollo for the Definition and
29	•	•	Procurement of the GEN System", dated 10
30			January 1973.
31		/	
32		2) 73-s	D-16 dated 2 February 1973.
33		. a)	Transmittal of January 1973 Review
34		į,	Presentation Material for SSTD GN&C~6.
35			
36	•	) 3) ` 73-s	D-30 dated 16 February 1973.
37 '	•	a)	Transmittal of Rough Draft of MIT/DI
38		÷	Prepared "GN&C Development Plan".
39			
40	•	4) 7.73-s:	D-35 dated 23 February 1973.
41	•	a)	Transmittal of Final Report on "GNEC
42	· / · · · · · · · · · · · · · · · · · ·	÷	Development Plan*.
	_		

		ı
1	U K :s	
2	•	TASK NO. SSTD-GN&C 7
3		
4	TITLE:	GN&C Analysis Math Models & Error Budgets
5		
6	OBJECTIVE:	Derive and document math models and error budgets
7		for all major GNEC assemblies (INU, Optics, etc)
8	,	and environment models (wind, gravity, etc) to
9		level of details required for use in performance
10	•	analysis studies. Both deterministic and
11		stochastic models shall be derived and will
12		include characteristics of ground based equipment,
13		i.e., TACANS, ILS, etc.
- 14	•	
15	STATUS:	Complete
16		
17	SD ENGINEERING	
18	CCNTACT:	M. Campbell
19		
20	DL ENGINEERING	
21	CONTACT:	N. Sears
22		
23	START/FINISH	
24	DATES:	17 November 1972 to 15 February 1973
25	•.	
26	EEPORTS AND	

SSTD GN&C-7 11/73

	os:
28	

SSTD GNEC-3,-48-7 were conducted together since the objectives were interdependent and required common simulation and analytical effort. The summary of the reports and memos issued for GNEC-3,-48-7 are listed under SSTD GNEC-3 only.

1	U K :s	,
2		TASK NO. SSTD-GN&C 8
3		
4	TITLE:	Review of GNEC Software Requirements
5		
6	OBJECTIVE:	Review and critique preliminary baseline software
7		requirements to determine adequacy of coverage and
8	•	level of detail. Review each identifiable module
9	•	considered with respect to correctness and depth
10	•	of definition, amount of structuring, and
11		partitioning of GNSC modules functions.
12	•	
13	STATUS:	Completed
14	•	
15	SD ENGINEERING	
16	CONTACT:	M. Campbell
17	•	
18	DI ENGINEERING	
19	CONTACT:	J. Kernan
20		
21	START/FINISH ·	
22	DATES:	17 November 1972 to 1 February 1973
23		
24	FEPORTS AND	,
25	menos:	
26	1)	72-SD-12 dated 21 December 1972.

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27		a) MIT/DL Report C-3875, "Review of Space
28	, in the second second	Shuttle GNEC Software Design
29		Requirements Document as a Flight
30		Programming Specification", dated 21
31		December 1972.
32		
33		2) 73-SD-17 dated 2 February 1973.
34		a) Transmittal of January 1973 Review
35	× .	Material Prepared for SSTD GN8C-8.

_	•	,
<b>1</b>	. U K :s	
2		TASK NO. SSTD-GNEC 9
3		
4	TITLE:	Entry Interface Dispersions and Navigation
5		Uncertainties
6		
7	OBJECTIVE:	•
8	•	1. Determine position and velocity deviation and
.9		navigation uncertainties at entry interface
10	• :	for Mission 3 with or without star-horizon
11		navigation updates and for a 7 day 100 mi
12	i de la companya de l	orbit using star-horizon navigation.
13		
14	•	2. Determine IMU alignment procedure and state
15	:	vector update procedure etc.
16		
17	STATUS:	Completed
18		
19	SD ENGINEERING	
20	CONTACT:	M. Campbell/M. Madden
21		
22	DL ENGINEERING	
23	CONTACT:	N. Sears/E. Muller
24		<b>t</b>
25	START/FINISH	
26	DATES:	26 December 1972 to 14 February 1973

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27		•	
28	REPORTS AND		•
29	MEMOS:		
30		1)	72-SD-17 dated 29 December 1972.
31			a) Transmittal of Memo to M. Madden from G.
32	•		Muller, dated 28 December 1973.
33 -			
34		2)	72-SD-18 dated 29 December 1972.
35			a) 23A STS Nemo No. 67-72, "Covariance of
36	•		Deviation in Flight-Path Angle at Entry
37	,		Interface", dated 22 December 1972.
38		•	
39		3)	73-SD-1 dated 5 January 1973.
40			a) Transmittal of Memo to M. Madden from G.
41	•		Muller, dated 4 December 1972.
42	•		
43	·. •	4)	73-SD-22 dated 14 February 1973.
44			a) 23A STS Memo No. 1-73, "Short Term
45	•		Performance of Shuttle IR Horizon
46			Sensing Orbit Navigation System <sup>n</sup> , dated
47			4 January 1973.
48			b) 23A STS Memo No. 2-73, "Entry Interface
49			Navigation Uncertainties", 4 January
50			1973.

1		U K :s	
2	,		TASK NO. SSTD-GNEC 10
3.			
4		TITLE:	Use of Transponder or Ground Tracking for INU
5			Calibration and Alignment During Boost and
6			Insertion.
7			
8	\$	OBJECTIVE:	Determine orbit insertion accuracies achievable
9	٠	1	using transponders or ground tracking for state
10	• .		updates and IMU calibration and alignment during
11	<b>3</b>		boost and insertion. Both gimballed platforms and
12	<u>į</u>		strapdown inertial reference units shall be
13	. !		considèred.
14			
15	•	STATUS:	Complete
16		•	
17		SD ENGINEERING	
18	¥	CCNTACT:	M. Campbell/M. Madden
19			
20		DL ENGINEERING	
21		CONTACT:	N. Sears
22			
23	•	START/FINISH	
24		DATES:	1 February 1973 to 2 May 1973.
25			
26		REPORTS AND	

27	MEMOS:			
28		1}	73-5	5D-19 dated 9 February 1973.
29			a)	Transmittal of January 1973 Review
30				Presentation Naterial for SSTD GN8C-10.
31				
32		2)	73-5	5D-55 dated 29 March 1973.
33			a)	23A STS Memo No. 21-73, "Refraction
34				Error Model for One-Way Dopplers, 8
35				March 1973.
36			` <b>b)</b>	23A STS Memo No. 22-73, "Measurement-
37	•			Sensitivity Vector for One-Way Doppler
38				during Powered-Boost Phase", 13 March
39				1973.
40				
41	•	3}	73-5	SD-57 dated 4 April 1973.
42	•		aj	23A STS Memo No. 27-73, "Including
43		•		Refraction and Transmitter Location Bias
44	•			Errors in One-Way Doppler Statistical
45				Analyses", 27 March 1973.
46				
47		4)	73-5	SD-75 dated 2 May 1973.
48		-	a)	23A STS Memo No. 38-73, "Boost Phase
49				Navigation Using One-Way Doppler and INU
50				Measurements", 5 May 1973.
51				•
52		5)	73-5	SD-86 dated 17 May 1973.
53			a)	23A STS Memo No. 41-73, "Shuttle
			•	SSTD GN&C-10 11/73

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57

58

59

- 6) 73-SD-102 8 June 1973.
  - 23A STS Memo No. 50-73, "Boost-Phase a) Navigation With One-Way Doppler and IMU Measurements", 29 May 1973.

	, , , , ,	
2		TASK NO. SSTD-GN&C 11
3		
4	TITLE:	Approach Guidance Energy Management Study
5		
6	OBJECTIVE:	Provide Consultation and analysis support of
7		McDonnell-Douglas Corporation (St. Louis) in their
8	•	simulation studies for SD of Shuttle orbiter
9	t ·	energy management techniques during transition and
10 .		approach.
11	•	
12	STATUS:	Completed
13		
14	SD ENGINEERING	
15 .	CONTACT:	H. Ehlers
16		
17	DL ENGINEERING	
18	CONTACT:	A. Elias
19		
20	START/FINISH	
21	DATES:	5 January 1973 to 20 March 1974.
22		
23	REPORTS AND	
24	memos:	•
25		1) 73-SD-8 dated 15 January 1973.

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27			a)	23A STS Memo #4-73, "Approach Guidance
28 -				can be used for Boost Aborts", dated 8
29				January 1973.
30	,		b)	Space Shuttle GN&C Equation Document
31	•	•		#23, "Energy Dissipation Rate Guidance
32				for Approach Phase", January 1973.
33	•			,
34		2}	73-9	SD-18 dated 9 February 1973.
35			a)	Transmittal of January 1973 Review
36				Presentation Material for SSTD GN&C-11.
37	•	•		
38		3)	73-9	5D-43 dated 8 March 1973.
39			a)	23A STS Memo No. 11-73, "Approach Phase
40				Guidance-New Results with Winds", dated
41	·			6 February 1973.
42	•		•	
43		4)	73-5	SD-62 dated 18 April 1973.
44	•		a)	23A STS Memo No. 29-73, "VORTAC
45				Reference Guidance System for Terminal
46		•		Area Energy Management (TAEM)", 2 April
47				1973.
48		-		•
49		5)	73-5	5D-79 dated 7 May 1973.
50			a)	23A STS Nemo No. 36-73, "Energy Rate
51				Switching Criterium for Vortac Reference
52				Guidance System," 26 April 1973.
c 2	·			

## SSTD GN&C-II APR 74

54			6)	73 <b>-</b> s	D-118 dated 27 July 1973.
55 ·		•		a)	23A STS Memo No. 61-73, "Targeting
56			*		Criteria for TAEM Guidance", 16 July
57				•	1973.
58					
59				b)	23A STS Memo No. 62-73, "Wind
60					Compensation Problems in TAEM Guidance",
61	•				17 July 1973.
62					
63		•	7)	74-s	D-3 dated 5 February 1974.
64	•	• .		a)	Shuttle Memo No. 10E-74-1, "Interface
65 ·					Between Alpha Transition and TAEM
66	,	• .			Phases", 18 January 1974.
6 <b>7</b>					
58		•	8)	74-s	D-18 dated 5 April 1974.
69			•	a)	CSDL Report C-4082, "Space Shuttle G&N
70	,				Equation Document No. 27, Terminal
71	•				Area Energy Management (TAEM)
72					Guidance," March 1974.
73					

1	U K :s	
2		TASK NO. SSTD-GNEC 12
3	•	
ų	TITLE:	Backup GN&C Computer Minimal Sizing
4 5 ·		
6	OBJECTIVE:	Considering more than half of the storage space in
7		the onboard backup GNSC computer is allocated for
8		system functions (housekeeping), conduct a study
9		to determine maximum in depth reduction of these
10		functions. In particular, investigate minimal
11	i i	display, control and moding and FDI (replace with
· 12		simple voting mechanism) functions.
13	•	
14	STATUS:	Completed
15		
16	SD ENGINEERING	
17	CONTACT:	M. Chadwick
18		
19	DL ENGINEERING	
20	CONTACT:	J. Kernan
21		
22	START/PINISH	
23	DATES:	29 January 1973 to 16 February 1973
24	•	
25	PEPORTS AND	
26	HEMOS:	

1)	73-55-29	dated	16	February	1973.
٠,		44.44			

a) MIT/DL Shuttle Software Memo No. 51,
"Sizing of the GN&C System Functions",
dated 15 February 1973.

1	. UK:s	
2		TASK NO. SSTD-GN&C 13
3		<b>.</b>
4	TITLE:	Orbit Navigation Using Various Sensors
5		
6	OBJECTIVE:	Orbit navigation studies shall be performed for
7		missions to be specified including Missions 1,2 3A
8		€ 3B.
9	,	
10	STATUS:	Completed
11		
12.	SD ENGINEERING	
13	CONTACT:	M. Madden
14	•	
15	DL ENGINEERING	
16	CONTACT:	E. Muller
17		
18	START/FINISH	
19	DATES:	1 February 1973 to 1 October 1973 (Redirected to
20		SSTD GNEC-24 and 29.)
21		
22	REPORTS AND	
23	memos:	
24		1) 73-SD-42 dated 6 March 1973.
25		a) MIT/DL Memo from E. Muller to M.
26		Madden," GNSC TD No. 13 Orbit Navigation

SSTD GN&C-13 11/73

27	•.			Study", 2 March 1973.
28			b)	23A STS Memo No. 61-71, "Status Report
29		•		on Shuttle Ground Beacon Orbit
30	•		-	Navigational Analysis," 8 December 1971.
31	•	· •		· ·
32		2)	73-5	SD-50 dated 16 March 1973.
33	•		a)	23A STS Memo No. 20-73, "Orbital
34	,			Navigation Using Various Sensors", dated
35				8 March 1973.
36	,			
37		- 3)	73-5	5D-53 dated 21 March 1973.
38		•	a)	23A STS Memo No. 16-73, "Navigation
39				Sensor Study for a Short Mission (3A)",
40	•			dated 2 March 1973.
¥ <b>1</b>				
12		4)	73-5	5D-87 dated 17 May 1973.
43			a)	23A STS Memo No. 39-73, "Horizon Sensor
14	-		•	Error Study Using Correlated Noise with
45		·		a Six Component Sensor", 8 May 1973.
46	•	5)	73-5	5D-103 dated 13 June 1973.
47			a)	23A STS Nemo No. 51-73, "Navigation With
48				Altitude Measurements Only Using a
19	•			Horizon Sensor and a Radar Altimeter, 31
50	•			May 1973.

•	0 11 .5	•
2		TASK NO. SSTD-GN&C 14
, 3	·	
4	TITLE:	GN&C Performance Analysis for 150K Orbiter Design
- 5 ·		
6	OBJECTIVE:	An integrated GNSC analysis of several short
7		missions shall be performed to include missions
8		3A, 3B & several once-around missions.
9	•	
10	STATUS:	Completed
11		
12	SD ENGINEERING	
13	CCNTACT:	M. Madden
14		
15	DL ENGINNEERING	
16	CONTACT:	G. Levine
17	-	
18	START/FINISH	
19	CATES:	19 February 1973 to 2 August 1974.
- 20		
21	REPORTS AND	
22	MEMOS:	
23		1) 73-SD-27 dated 15 February 1973.
24		a) Acknowledgement of the Receipt of Data
25		from NR for SSTD GN&C-14.

	** .	•		
27		_ 2)	73-	SD-34 dated 23 February 1973.
28	·		a)	23A STS Memo No. 13-73, "Launch-Pad
29				Alignment of IMU by Gyro-Compassing
30				Effect of Gyro Errors on Alignment
31		•		Accuracy", dated 12 February 1973.
32				
33		3)	73-	SD-39 dated 28 February 1973.
34			a)	23A STS Memo No. 13-73 (Rev. 1),
35				"Launch-Pad Alighment of IMU by Gyro-
36	•			CompassingEffect of Gyro Errors on
37		٠		Alignment Accuracy", 12 February 1973.
38			b)	23A STS Memo No. 17-73, "Post-Blackout
39	•			Entry and Approach Phase Pootprints for
40				the NR 150K Orbiter Vehicle," dated 26
41			,	February 1973.
42			•	
43		4)	73-	5D-44 dated 7 March 1973.
44			a)	235 Memo No. 72-67, (Rev3), "Parameters
45				for GN&C Subsystem Error Models",
46				
47		5)	73-5	5D-48 dated 15 March 1973.
48			a)	DG Memo No. 1817, "Star Availability for
49	·			Space Shuttle IMU Alignment with Three
50				Star Trackers", dated 3 March 1973.
51				
52		6)	73-5	5D-48A dated 17 April 1973.
53			a)	23S Memo No. 78-73, "Kalman Filtering of

54				Star Measurements for Space Shuttle IMU
55				Alignment", dated 18 April 1973.
56				
57		7)	73-	SD-49 dated 16 March 1973.
58		•	a)	23N STS Memo No. 11, "Black-out of Radio
59				Transmission During Re-entry of STS",
60	•			dated 10 September 1970.
61	,			· · · · · · · · · · · · · · · · · · ·
62	•	. 8)	73-	SD~56 dated 30 March 1973.
63			(a)	23A STS Memo No. 19-73, "Approach and
64		<b>b</b>		Landing Navigation Performance Using
65				Updated VOR/DME AND ILS ERROR MODELS, # 8
66	·			March 1973.
67				
68		. 9)	73-5	5D~59 dated 9 April 1793.
69	•		a)	Transmittal of Space Shuttle GN&C
70				Equation Documents pertinent to SSTD
71	• .			GNEC-14, (16 documents).
72				
73	•	10)	73-5	5D-63 dated 18 March 1973.
74		•		
75			<b>a</b> )	23A STS Memo No. 10-71, "Drag
76	•	•	-	Measurement as a Possible Means for
77				Reducing Altitude Estimation Errors
78			•	During SSV Entry," 25 January 1971.
79			b)	23A STS Memo No. 26-71 "Stabilization of
30				the Altitude Component of the Orbiters

81	1		State-Vector Estimate During Entry", 9
82			April 1971.
83		,	c) 23A STS Memo No. 10-73, "Entry Approach
84			and Landing Navigation Studies", 2
85		•	Frbruary 1973.
86			
87	,	11)	73-SD-91 dated 23 May 1973.
88		-	a) 23A STS Memo No. 42-73 "Guidance and
89			Navigation System Performance Study for
90			Mission 3A Aborts", 11 May 1973.
91	4.	•	b) 23A STS Memo No 45-73, "Sensitivity of
92	· ·		State Estimination Errors to IMU Initial
93			Alignment ErrorsEstimation and IMO
94			Errors", 16 May 1973.
95	*		c) 23A Memo No. 46-73, "Calculation of IMU
96	٠		Error Sensitivities from Correlations
97			Between State-Estimation and IMU
98	• .		Errors", 16 May 1973.
99	·		
100		12)	73-SD-95 dated 30 May 1973.
101 -			a) 23A STS Memo No. 48-73, "Shuttle Entry
102	,		and Transition Phase Guidance
103			(Viewgraphs)", 21 May 1973.
104			
105		13)	73-SD-97 dated 1 June 1973.
106			a) 23A STS Memo No. 49-73, "Recent Approach
107	·		and Landing Navigation Studies", 29 May

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	* · · ·			
80				1973.
109		14)	73-	SD-99 dated 7 June 1973.
10		· ·	a)	235 Memo No. 72-67, Rev. 4, "Parameters
11	•			for GN&C Subsystem Error Models", 6 June
12				1973.
13	•			
14		15)	73-	SD-108 dated 2 July 1973.
15	•		a)	23A STS Memo No. 54-73, "Sensitivity of
16	,		-	Required TPS Weight to Variations in
17		•		Vehicle State at Entry Interface,
18				-Mission 3A Abort", 18 June 1973.
19	•		b)	23A STS Memo No. 56-73, "Additional IMO
20		,		Performance Studies for Mission 3A
21				Abort", 18 June 1973.
22	e e			
23		16)	73~9	5D-14 dated 20 July 1973.
24			a)	23A STS Memo No. 63-73, "Navigation-
25			•	System Performance for 3A~Abort Mission-
26				Latter Part of Entry to Touchdown", 12
27				July 1973.
28				•
29	•	17)	73-9	SD-115 dated 23 July 1973.
30			a)	23A STS Memo No. 55-73, "Thrust
31				Direction Turning Rate for Large Central
32				Angle Shuttle Deorbit Maneuvers", 19
33 -				June 1973.
34	•		b)	23A STS Memo No. 57-73, "Effect of

			•		
35					Performing Shuttle Deorbit at T/W
36	- -				Different from Targeted Value", 20 June
37					1973.
38				C)	23A STS Memo No. 58-73, "The Space
39				•	Shuttle Project Should Use Ephemeris
40					Time Rate and Ephemeris Time (of day),"
41		,			3 June 1973,
42					<b>*·.</b>
43			- 18)	73-9	SD-122 dated 1 August 1973.
44				a)	23A STS Memo No. 66-73, "Mission
45			•		#3A-Abort Performance Data with One-Way
46					Doppler Measurements During Boost", 1
47	•	•			August 1973. SSTD GN&C-14 6/73.
48	:		19)	73-s	5D-143 dated 13 September 1973.
49	:	•		a)	10E STS Memo No. 71-73, "The Leap
50		,			Second", 11 September 1973.
51			•	•	
52			20)	73-S	D-147 dated 21 September 1973.
53	٠	•		a)	10E STS Memo No. 74-73, "Generation of
54					Maximum Range RTLS Glide Trajectory 17
55					September 1973.
56					
5 <b>7</b>			21)	73 <b>-</b> S	D-150 dated 10 October 1973.
8				a)	10E STS Memo No. 75-73, "Verification of
59					the Unified Powered Flight Guidance
50					Program", 27 September 1973.
. 1				b)	CSDL Memo dated 17 September from J.P.
				ν,	

16.2	•		Higgins, "Errata for Space Hsuttle GN&C
16 <b>3</b> ·		, '	Equation Document No. 24, Unified Power
164	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -		Flight Guidance, June 1973".
165			
166		22)	73-SD-159 dated 9 November 1973.
167	<b>≺</b>		a) 10E STS Memo No. 80-73, "Maximum Range
168	• •		RTLS Glide Trajectories from 205,000
169	•		Ft"., 2 November 1973.
170			
171		23)	73-SD-173 dated 12 December 1973.
172	•		a) 10E STS Memo No. 85-73, "Astronaut
173	•	•	Modification of the Rendezvous
174			Sequence," 5 December 1973.

1	U K :s	
2	e is a second of the second of	TASK No. SSTD-GN&C 15
3		
4	TITLE:	GNEC Vehicle Software RPD Definition
5	•	
6	OBJECTIVE:	Conduct a study to determine a) the format and
. 7		arrangement of each RFD to facilitate integration
8		of the group, b) the potential problems inherent
9		in the integration process, and c) preferred
10	•	methodology for integration.
11		
12	STATUS:	Complete
13		
14	SD ENGINEERING	
15	CONTACT:	D. Engels
16		
17	DL ENGINEFRING	
18	CCNTACT:	N. Sears
19		
20	START/FINISH	
21	DATES:	1 February 1973 to 1 May 1973
22		
23	REPORTS AND	
24	nemos:	t
25		1) 73-SD-73 dated 26 February 1973.
26		a) MIT/DL Report No. C-3899, "Design of the

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27	·			GNEC Flig	ht Software :	Specific	ation	", 26
28		·		February 1	973.		•	
29		·	•	, .				
30		2)	73-	SD-74 dated	1 May 1973.		·	<b>.</b>
31	•		a)	Shuttle	Management	Мето	No.	25,
32				*Examples	of Shuttle	e GN&C	Soft	tware
33		:	•	Specificat	ions", 30 Apr	il 1973		de La
	•							

1	U K :s	
2		TASK NO. SSTD-GNEC 16
3		
4	TITLE:	GN&C Performance Requirements Report
5		
6	OBJECTIVE:	
7.		1. Determine the functional and performance
8		requirements of the G&N subsystem and its
9	,	major components (e.g. IMU).
10		
11		2. Prepare and deliver a report describing these
12		requirements, the error models used, error
13		sensitivities and error budgets for G&N
14		components.
15		
16		3. This SSTD is the preparation of the final
17		report for SSTD GN&C-14.
18		
	STATUS:	Completed
19		Completed
20	•	
21	SD ENGINEERING	
22	CONTACT:	D. Engels
23		
24	DL ENGINEERING	
25	CCNTACT:	G. Levine

27 START/FINISH

28 DATES: 1 March 1973 to 2 August 1974.

29

30 FEFORTS AND

31 MEMOS:

32 This SSTD is essentially preparations of the second of the seco

37

38

39

40

This SSTD is essentially preparing a report of the GNEC Performance Requirements and Functional Requirements as determined by the simulation effort of SSTD GNEC-14. The SD agreed to accept the documents listed under SSTD GNEC-14 as the initial documentation of results obtained to date, and future effort under SSTD GNEC-14 be documented as various simulation results as they are completed.

1		U K :s	
2	•		TASK NO. SSTD-GN&C 17
<b>3</b> .	•		
4	•	TITLE:	GNSC Operating System Software Definition
5			
6		OBJECTIVE:	
7			1) Define and describe the contents of the
8			following functions in the GN&C computer:
9			System utility, subroutine library, subsystem
10-	*		control and moding, subsystem fault detection
11	. ' .	· ""	and isolation, subsystem calibration and
12			testing, common pool and temporary storage,
13			entry routines.
14	. "		
15		STATUS:	Complete
16			
17		SD ENGINEERING	
18		CONTACT:	M. Chadwick
19			
20		DL ENGINEERING	
21	•	CONTACT	J. Kernan
22			
23		START/FINISH	
24		DATES:	15 February 1973 to 18 May 1973.
25			
26	·	REPORTS AND	

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27	MEMOS:		
28		P <sub>m</sub>	
29	1;	73-SD-29 dated 16 February 1973.	
30		a) MIT/DL Shuttle Software Memo No. 51	۱,
31		"Sizing of the GNEC System Punctions"	٠,
32.		dated 15 February 1973.	
33			
34	2)	2) 73-SD-90 dated 18 May 1973.	٠,
35		a) MIT/DL Shuttle Software Memo No. 52	<b>?</b> ,
36		"Description and Size of GN&C Syste	) m
37		Functions", 15 May 1973.	•

1		U K :s	
2		- ,	TASK NO. SSTD-GN&C 18
3		٠.	
4		TITLE:	Summary of MIT/DL Analysis Programs
5.			
6		OBJECTIVE:	Prepare and deliver to SD a summary list of the
7			computer programs in use or available for use at
8		• .	MIT/DL of value for current and future analysis of
9			Space Shuttle GN&C and provide a brief description
10			of each.
11	-	•	
12		STATUS:	Complete
13			
14		SD ENGINEFRING	
15		CONTACT:	M. Chadwick
16	. •		
17	٠	DL ENGINEERING	
18		CONTACT:	G. Levine
19			
20		START/FINISH	
21	• •	DATES: 3	1 March 1973 to 15 June 1973
22			
23		REPORTS AND	
24		menos:	
25	•		1) 73-SD-47 dated 14 March 1973.
26		•	a) 23% SGA Memo No. 4-72, "General Least.
		· .	
		• • • • • • • • • • • • • • • • • • •	SSTD GN&C-18 11/73
			·

			Square, Least Power, and Chebyshev
	٠.		Function Fitting Subroutines for
			Discrete Point Sets", dated 12 September
	•.		1972.
		•	
		b)	Space Shuttle GN&C Equation Document No.
			4 Rev. 3, "Precision State and Filter
			Weighting Natrix Extrapolation."
	•	C)	Space Shuttle GN&C Equation Document No.
			10, Rev. 1, "Conic Required Velocity
		•	Determination".
	,	d)	MIT/DL Memo "Users Guide to SMRSS7.
		u,	
			LAMBERT", dated 18 November 1971.
		6)	Space Shuttle GN&C Equation Document No.
			5, Rev 2., "Rapid Real-time State and
,			Filter Weighting Matrix Advancement
	,		During Specific Force Sensing",
	÷		
*		f)	23A STS Memo No. 47-72, "Numerical
· .·			Integration of the W-Matrix by the
2			Average-G (Heun) Method", dated 16
			August 1973.
		g)	23A STS Memo No. 18-73, "WMR.
•	Marin St.		
	•		SSTD GN&C-18 11/73

54	•			ASTRODYN-A Comprehensive MAC Subroutine
55				for Astrodynamic Calculation", dated 1
56				March 1973.
57	·		-	
58			h)	MAC Program Cards and Listing for
59			, <u>j</u>	LEASTSQR, LEASTPWR, CHEBSHEV, TEST
				LEASTSQ and TEST CHEBSHEV.
60				LEASING and IEST CREBBALV.
61			2.	MAC Drogwam Cardo and lighing for
. 62			i)	MAC Program Cards and Listing for
63				RVWXHEUN, RVWXTRAP, and KEPLER.
64	•		,	
65			j)	MAC Program Cards and Listing for
66		•		LAMBERT, MRSHRINV, KPLREON AND SEARCH,
67				
68			k)	MAC Program Listing for WMR. ASTRODYN.
69				
70		2)	73-9	5D-58 dated 5 April 1973.
71			a)	23A STS Memo No. 30-73, "Summary of
72		•	٠	MIT/DL Astrodynamic and Mathematical
73				Analysis Programs" 3 April 1973.
74				
75	**************************************	3)	73-5	5D-64 dated 19 April 1973.
76			a)	MIT/DL Memo to M.C Chadwick from E.S.
77	· · · · · · · · · · · · · · · · · · ·			Muller, "MIT/DL Rendezvous and Orbit
78				Navigation Analysis Computer Programs",
79		ı	-	16 April 1973.
80			` b}	MIT/DL Memo to M.C. Chadwick from J.
00			• •	
				SSTD GN&C-18 11/73

8 1 8 2 8 3				Higgins, "Shuttle Boost Simulator," 19 April 1973.
84		4}	73-	SD-78 dated 3 May 1973.
85			<b>a</b> }	MIT/DL Memo to M. Madden from E. Muller,
36 <sup>-</sup>			•	"Transmittal of Program Decks and
87				Listings for Error Vector Generation
88				Routine", dated 3 May 1973.
89				
90	,	5)	73-	SD-84 dated 15 May 1973.
91			a)	23A SGA Memo No. 2-73, "Adding Process
92		•		Noise to a Square Rout Covariance Matrix
93				via "REP. HOUSEBIG", 14 May 1973
94				
95			þ)	Kaminski, et al., IEEF Transactions on
96			•	Control, Vol. AC-16 No. 6, December
97		,		1971, "Discrete Square Foot Filtering, A
98				Survey of Current Techniques".
99				
00			c)	23A STS Memo No. 49, "MAC Programs to:
1				Triangularize a Matrix by Householder
)2	·		-	Transformations".
3				
)4	*		dj	Program Listing and Cards for the
)5				REP. HOUSEBIG Program.
7		6)	73-5	SD-105 dated 15 June 1973.
	•		. •	SSTD GN&C-18 11/73

108			a)	MIT/DL Memo from B. Kriegsman to D.
109	•	•		Engel, "Guidance and Navigation Systems
110		•		Analysis Programs-Boost, Entry and
111			٠	Landing, " 13 June 1973.

1	u K ts	
2		TASK NO. SSTD-GNEC 19
3		<b>.</b>
. 4	TITLE:	Passive Rendezvous Sensor Requirements Definition
5		
6	OBJECTIVE:	Define and describe functional and performance
7	•	requirements for a Shuttle passive rendezvous
8		sensor.
. 9		
10	. STATUS:	Complete
11		
12	SD ENGINEERING	
13	CONTACT:	R. Varian/A. Bologna
14		
15	DL ENGINEERING	•
16	CONTACT:	G. Levine/E. Muller
17		
18	START/FINISH	·
19	DATES:	1 February 1973 to 20 February 1973.
20	•	
21	REPORTS' AND	
22	hemos:	
23		1) 73-SD-32 dated 20 February 1973.
24	•	a) MIT/DL Memo, "Passive Rendezvous Study
25		Results (Task 19)" dated 16 February
26		1973.

SSTD GN&C-19 11/73

2)	73-SD-38	dated	27	Pebruary	1973.
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- a) MIT/DL Memo, "Continuation of the Passive Rendezvous Sensor Requirements Definition Task," dated 26 February 1973.
- 3) 73-SD-51 dated 19 March 1973.
  - a) MIT/DL Nemo, "Updated Radar Search Angle
    Requirements for Mission 3B", dated 16
    March 1973.

1	U K is	•		•		•
2		-			TASK NO.	SSTD-GN&C 20
3				· · · · · · · · · · · · · · · · · · ·		
4	TITLE:	Simplified	Shuttle	Abort GEN	Study	two controls
5			à.			
6	OBJECTIVE:	TBD				
7				4	÷	
8	STATUS:	Withdrawn				
9			•			
10	SD ENGINEERING			٠,		· .
11	CCNTACT:	D. Engels			•	•
12	•					· .
13	DL ENGINEERING				•	
14	CCNTACT:	N. Sears		-		•
15	· :				•	
16	START/FINISH			. •	*,*	•
17	DATES:	TBD				
18		. •		•		
19	REPORTS AND	•	٤.,			·
20.	MEMOS:			. •	<del>*</del>	
21	• • • • • • • • • • • • • • • • • • •					
	•					·

U K :s

TASK NO. SSTD-GN&C 21

1 .

TITLE:

IMU Derived Attitude and Attitude Rate

OBJECTIVE:

16-17"

Determine the attitude and angular rate characteristics which can be derived from IMU information. Determine the accuracy of the attitude and rate estimates obtainable in terms of random noise, bias, quantization and effective bandwidth.

Preliminary results shall consist of the achievable on-orbit accuracy with parametric gimbal transducer quantization of 20, 40, and 80 arc seconds with and without the use of star tracker data.

Final results shall include an update of the above (if required), and shall consider ascent and entry in addition to on-orbit. Final results shall also consider the existence of other error contributors and allow application of the results to different candidate IRU's and off-nominal mission conditions.

27	STATUS:	Completed
28		
29	SD ENGINEERING	
30	CONTACT:	J. Jansen
31		
32	DL ENGINEERING	
33	CONTACT:	G. Edmonds/R. Schlundt
34		
35	START/FINISH	
36	DATES:	9 April 1973 to 23 April 1973.
37	•	
38	REPORTS AND	
39	Memos:	
40		1) 73-SD-80 dated 8 may 1973.
41		a) SSV Memo No. 73-23C-7, "State Estimator
42		for the Shuttle On-Orbit Autopilot," 19
43		April 1973.
44		b) SSV Memo No. 73-23C-8, "On-Orbit Angular
45		Velocity Estimation Accuracies Using IMU
46	•	Gimbal Angle Measurements", 1 May 1973.

1	U K :s	•
2		TASK NO. SSTD-GN&C 22
3		
4	TITLE:	Passive Rendezvous Sensor Requirements Definition
5	<b>₽</b> 1	(Extension)
6		
7	OBJECTIVE:	
8		1) Define required measured parameters and
9		required accuracy of these measurements
10		(random and bias) for Mission 3B for two
11		basic operational modes:
12		a) Automatic assumes filtering of
13		navigation measurements (e.g. using the
14		Unified Navigation Filter) and automatic
15		execution of braking and LOS cor-
16	•	rections.
17	ν . 4	b) Manual assumes display of raw
18		measurement data from which astronaut
19		can make appropriate braking and LOS
20		corrections.
2 1.	3.	Measurements considered will be: range,
22		range rate, LOS angles, angle rates.
23	* ************************************	2) Define sensor requirements (accuracies,
24		maximum acquisition range) for general
25		passive rendezvous mission (other than 3B).
26		a) Consider using star tracker to track

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27		target using reflected sunlight at long
28	,	ranges with skin tracking radar at short
29		ranges.
30		b) Examine different possible rendezvous
31	·	trajectories.
32 .		3) Determine sources and magnitudes of max-min
33	•	range limits for conduct of rendezvous
34		mission 3B.
35		
36		(this TD is an extension of TD #GN&C-19)
37 '		
38	STATUS:	Completed
39		
40	SD ENGINEERING	
41	CONTACT:	M. Campbell
42		
43	DL ENGINEERING	
<b>† 4</b>	CONTACT:	N. Sears
15		
<b>1</b> 6	START/FINISH	
17	DATES:	14 March 1973 to 1 October 1973.
18	<b>&gt;</b> -	
19	REPORTS AND	
60	MEMOS:	
i <b>1</b>	•	1) 73-SD-51 dated 19 March 1973.
2		a) MIT/DL Memo, "Updated Radar Search Angle
3		Requirements for Mission 3B (Task 19),"

4				dated 16 March 1973.
5				
6		2)	73-9	SD-67 dated 24 April 1973.
7			a.)	MIT/DL Memo to A. Bologna, "TD No. 22
8		•		(Fendezvous Sensor Study)", from E.
9				Muller, dated 24 April 1973.
0			•	
1		3)	73-8	5D-70 dated 24 April 1973.
2	•		á.)	23A STS Memo No. 33-73, "Orbiter
3			٠	Rendezvous and Terminal Phase Analysis
4	•		3	(Viewgraphs)", 19 April 1973.
5				
6	•	4)	73-5	SD-72 dated 26 April 1973.
7		•	a)	MIT/DL Memo to A. Bologna, "TD No. 22
8				(Rendezvous Sensor Study)", from E.
9				Muller, dated 26 April 1973.
ro				
71		5)	73-5	5D-88 dated 17 May 1973.
2			a) -	23A STS Memo No. 52-71, "The Secondary
13				Constraints Employed in the Orbiter
4	•		٠	Rendezvous Targeting Program", 15
5	<b>V</b> -	4		October 1971.
6			b)	23A STS Memo No. 55-71, "A Skylab
7				Rendezvous Trajectory Computed with the
8				Orbiter Targeting Program", 12 October
19				1971.
0			c)	23A STS Memo No. 8-72, "The Iterative
_				
				SSTD GN&C-22 11/73
	•			- Control of the Cont

81	•			Algorithm Used, in the Elevation Angle
82				Search in the Rendezvous Targeting
83				Program", 11 February 1972.
84			. d)	23A STS Memo No. 9-72, "Users Guide to
85				the Shuttle Rendezvous Targeting
86		•	•	Program", 12 March 1972.
87			e)	23A STS Memo No. 15-72, The Design of
88				the Shuttle Rendezvous Targeting
89	•			Program", 8 March 1972.
90	•		£)	23A STS Memo No. 35-73, "The Computation
91	•	•	·	of the Mission 2 Rendezvous Profile
92		,		Using the Shuttle Rendezvous Targeting
93	•	:		Program", 2 May 1973.
94			g)	MIT/DL Report E-2713, "Rendezvous
95				Targeting for Space Missions", September
96				1972.
97	•			
98	-	6)	73-s	SD-89 dated 17 May 1973.
99			a)	23A STS Memo No. 44-73, "Rendezvous
100			•	Sensor Requirements for Long Range
101	•			Rendezvous Missions and Search Angle
102	· · · · <b>\</b>			Requirements for Mission 3B", 15 May
103				1973.
104			,	
105		7)	73-s	D-92, dated 23 May 1973.
106		•	<b>a</b> )	MIT/DL Memo to R. Reid from E. Muller,
107			•	"TD Nos. 22 and 23", 22 May 1973.
•				The same was a same way is a same
			,	SSTD GN&C-22 11/73
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3	•
4	TITLE:
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6	•
7	OBJECTIVE:
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10	•
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18	•.
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22	<i>.</i>
23	
24	
25	

TASK NO. SSTD-GN&C 23

Effect of Thermal Conditioning Operation on Shuttle Navigation System Performance

In order to determine the effect of thermal conditioning operations on orbiter navigation system performance a parameter study is required. The following task is defined to aid in generating the desired data for this study.

Determine the on-orbit navigational performance degradation between the baseline navigation technique (wings level using horizon sensors) and a barbecue (BBQ) navigation technique (slow roll obtaining horizon measurements when the sensor configuration centerline passes through nadir) assuming 8 hours without navigation followed by 3 to 12 hours of

- a. baseline navigation to steady-state condition (no BBQ).
- b. BBQ navigation, with a single measurement made every 12 min, to steadystate or 12 hours whichever occurs first.
- c. BBQ navigation with a single measurement made

27		every 20 min to steadystate or 12 hours
28		whichever occur first.
29	•	d. Case b. and c. augmented with altitude data.
30		e. Case b. and c. with horizon sensors replaced
31	•	with one-way doppler for which measurement
32		frequency and durations are TBD.
33		
34		Performance will be evaluated by comparing
35		on-orbit covariance matrices after 1, 1.5, 2, 3,
36		and 5.5 hours of navigation and by comparing entry
37	•	interface covariance matrices and flight path
38		angle uncertainites after navigation periods of
39		1.5, 5.5 hours, and after steadystate or 12 hours.
40	•	
<b>1</b> 1		Assumptions and Initial Conditions
42		
+3	•	1. Eight hours of on-orbit operation without
14	<i>(</i>	navigation.
15.		2. IMU alignment allowed just prior to the
46		initiation of navigation.
17		3. Initial SV and alignment accuracies
18	Ž.	consistent with 1. and 2.
19		4. BBQ mode performed with body X axis in the
50		orbit plane and perpendicular to the sun line
51		(sun synchronous orbit). Roll motion is
52		maintained about this axis at 0.5 deg/sec
3	•	(0.3 deg/sec for case c) while the X axis is

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54		maintained locally level by a normal to the
55		orbit plane rotation at orbit rate.
56		5. The orbital parameters for the circular orbit
57		are
58		i = 104 deg
59	:	h = 100 nm
60		
61		6. The deorbit maneuver requirements assume
62		baseline deorbit (single OMS retro) for 150K
63	•	1b. Orbiter and TBD 1b. payload and
64	•	propellant load.
65		7. Coverage for one-way doppler will be such
66		that the frequency of tracking periods will
67	•	be TBD and the duration of tracking will be
68	•	TBD for each period. Tracking stations will
69	•	be TBD only. Assume max utilization: i.e.,
70	•	nav. sequence begins at a lat-long such that
71		the greatest number of ground stations can be
72	•	used during the nav. period.
73		
74	STATUS:	Completed
75	3.	
76	SD ENGINEERING	
77	CONTACT:	R. Reid
78	•	<b>*</b>
79	DL ENGINEERING	
80	CONTACT:	E. Muller
		SSTD GN&C-23 11/73

81				
82	START/FINISH			
83	DATES:	9 A 1	ril 1973	to 22 April 1973
84		-		
85	REPORTS AND		•	
86	menos:			
87		1)	73-SD-6	5 dated 23 April 1973.
88	•		a) MI	T/DL Memo to M. Madden, "TD No. 23",
89			fr	om E. Muller, dated 20 April 1973.
90				
91	•	2)	73-SD-7	3 dated 30 April 1973.
92	•		a) MI	T/DL Memo to M. Madden, "TD No. 23
93			<b>(</b> C	ase e - One-Way Doppler)", from E.
94	•	•	២ប	ller 27 April 1973.
95				
96		3)	73-SD-7	6 dated 2 May 1973.
97			a) MI	T/DL Memo to R. Reid, "TD No. 23",
98	•		fr	om E. Muller dated 30 April 1973.
99		4)	73-SD-9	2 dated 23 May 1973.
00			a) MI	T/DL Memo to P. Reid, "TD Nos. 22 and
01			23	", from E. Muller, 22 May 1973.
02	· • • • • • • • • • • • • • • • • • • •	5)	73-SD-9	3 dated 22 May 1973.
03			a) 23	A STS Nemo No. 43-73, "Effect of
04		•	Ba	rbeque Mode and Doppler Antenna
05			Co	nstraints on Shuttle Orbit Navigation
06			Pe	rformance", 15 May 1973.

1	U K :s	
2	· · · · · · · · · · · · · · · · · · ·	TASK NO. SSTD-GN&C 24
3		•
4	TITLE:	Support of Navigation Evaluation
5		
6	OBJECTIVE:	Design and run a number of test cases in order, to
7		support the evaluation and comparison of the TRW
8		and Draper Laboratory navigation filters. Also
9		provide technical consulation as required to
10		support this effort.
11		
12	STATUS:	Terminated
<b>13</b>		
14	SD ENGINEERING	
15	CONTACT:	D. Engels
16		
17	DL ENGINEFRING	· '
18	CCNTACT:	G. Levine
19		
20	START/FINISH	
21	DATES:	20 April 1973 to 2 August 1974.
22		
23	REPORTS AND	
24	MENOS:	
25		1) 73-SD-68 dated 24 April 1973.
26	•	a) Notification to the SD of transmittal of

27	•	the following documents to Intermetrics.
28	b}	MSC Internal Note No. 71-FM-343, "State
29		Propagation in the Mulitphase Filter", dated
30		August 30, 1971.
31	c)	MIT/DL E-2637, "Results of Space Shuttle
32		Computer Floating - Point Precision Study",
33		January 1972.
34	đ)	Space Shuttle GN&C Equation Document No. 5,
35		Rev 2, "Rapid Real-Time State and Filter
36		Weighting Matrix Advancement during Specific
37	•	Force Sensing", November 1972.
38	e}	Space Shuttle GN&C Equation Document No. 4
39		Rev. 3, "Precision State and Filter-
40	•	Weighting Matrix Extrapolation", October
41		1972.
42	f)	Space Shuttle GN&C Equation Document No. 3
43		Rev. 2, "Conic State Extrapolation", October
44		1972.
45	<b>a</b> )	Space Shuttle GNEC Equation Document No. 12,
46		Rev. 2, "Entry Approach and Landing
47		Navigation".
48	h)	Space Shuttle GNEC Equation Document No. 16,
49		"Station-Keeping Navigation", March 1972.
50	i)	Space Shuttle GN&C Equation Document No. 21,
51		"Shuttle Unified Navigation Filter", November
52		1972.
53	1)	"Ground Beacon Orbit Navigation Analysis",
,		
:		SSTD GN&C -24 AUG 74

54	· ·		E.S. Muller Jr. MIT/CSDL.
5	•	·k)	23A STS Memo No. 11-72, "Entry and Terminal
66			Phase Navigation for SSV Orbiter Using MLS or
7			AILS, and VOR/DME", 16 February 1973.
8	,	1)	23% STS Memo No. 23-72, "Entry, Approach and
9			Landing Navigation Routine", 28 March 1972.
0		m)	23A STS Memo No. 41-72, "Navigation Errors on
i 1			Various Shuttle Approach Trajectories", 14
52		•	June 1972.
; 3	•	n)	23A STS Memo No. 44-72, June 1972. "Scheme
54	•		of Inhibiting Crosstrack Updates on Near
55			Direct Overhead Beacon Passes (Shuttle Ground
56			Beacon Orbit Navigation System)", 1 August
			1972.
57	,	۵١.	
8	•	0)	
59			Errors Using Various Navigation Aids During a
70	-		Space Shuttle Reentry and Landing", 17
11			October 1972.
72		P)	23h STS Memo No. 68-72, W-Matrix Propagation
73	•		Using an Approximate Driving Noise Model, 2
74	•		January 1973.
75	ν.	₫)	23A STS Memo No. 5-73, ILS Error Model for
76			Shuttle Approach and Landing Navigation
77	<i>\$</i>		Studies", 18 January 1973.
78	, ·	· r)	23A STS Memo No. 9-73, "Shuttle Navigation
79			Filter Presentation at MSC (MPAD) Meeting, 18
30			January 1973", 1 February 1973.
			COTTO CNIC ON AUG 74
			SSTD GN&C -24 AUG 74

81		s)	23A STS Memo No. 10-73, "Entry Approach and
82	·		Landing Navigation Studies", 2 February 1973.
83		t)	23A STS Memo No. 12-73, "Recommended Filter
84			State Dimension in Unified Navigation Filter
85	•		for Each Shuttle Mission Phase", 6 Pebruary
86			1973.
87		u)	23A STS Memo No. 19-73, "Approach and Landing
88			Navigation Performance Using Updated VOR/DME
89			and ILS Error Models", 8 March 1973.
90			
91.	•	2)	73-SD-69 dated 23 April 1973.
92			a) Transmittal letter to Intermetrics of
93	·		documents listed above for 73-SD-68.
94			
95	•	3)	73-SD-82 dated 11 May 1973.
96			a) Transmittal of the following memo to
97			Intermetrics: Space Guidance Analysis
98	•	,	Memo No. 4-70, "Explicit Analytic
99			Expressions for the Terms in a Spherical
100			Harmonic Expansion of the Gravitational
101		•	Acceleration Due to Oblateness", 26 May
102	3		1973.
103	:		
104		4)	73-SD-123 dated 3 August 1973.
105			a) CSDL Memo to D. Engels from E. Muller/P.
106			Kachmar, "Test Case Results for TD No.
107			24", 31 July 1973.
-			

135	•			January 1974.
136	•			•
137			b)	Shuttle Memo No. 10E-74-3, "Measurement
138				Residuals on Selected Entry and Landing
139				Simulation Runs," 29 January 1974.
140				
141		10)	74-S	SD-6 dated 15 February 1974.
142			a)	Shuttle Memo No. 10E-74-4, "Comparison
143				of Entry-Navigation-Filter UnderWei-
144	•			ghting Schemes with Large Initial
145	•	-		Condition Errors", 31 January 1974.
146		•		· · · · · · · · · · · · · · · · · · ·
147			b)	Shuttle Memo No. 10E-74-5, "Navigation
148	e e e			Errors During Entry-No TACAN, Baro or
149				OWD Updates", 5 February 1974.
150	· •			
151	•	*	c)	Shuttle Memo No. 10E-74-10, "Shuttle
152				Navigation Filter Evaluation (Orbit
153				Navigation)," 6 February 1974.
154	•			
155	, , , , , , , , , , , , , , , , , , ,	11)	74-S	D-7 dated 4 March 1974.
156	<b>v</b> .		a)	Shuttle Memo No. 10E-74-11, "Small State
157				Size and Low Update Rates for the
158	2	•		Entry-and-Landing Navigation Filter", 7
159		•		Pebruary 1974.
160				
61	,	121	74-S	D-9 dated 12 March 1978

162			a)	Shuttle Memo No.	10E-74-7, "Shuttle
163				Navigation Pilter	Evaluation Mission
164				Phase: Rendezvous	(No. 2 of 4)", 12
165			•	February 1974.	
166	· •		•		
167		13}	74-s	D-11 dated 14 March 1	974.
168			a)	Shuttle Memo No.	10E-74-6, "Shuttle
169				Navigation Filter	Evaluation Mission
170				Phase: Rendezvous	(No. 1 of 4)," 6
171				February 1974.	
172	•			•	•
173		14)	74-s	D-15 dated 28 March 1	974.
174	·		a)	Shuttle Memo No.	10E-74-9, "Shuttle,
175				Navigation Filter	Evaluation Mission
176				Phase: Rendezvous	(No. 4 of 4)," 20
177	•			February 1974.	•
178					•
179	- ·	15)	74-S	D-16 dated 29 March 1	974.
180			:3)	Shuttle Memo No.	102-74-8, "Shuttle
181				Navigation Filter	Evaluation Mission
182	*			Phase: Rendezvous	(No. 3 of 4)," 20
183	<b>1.</b> ·			February 1974.	
184					e e
185	7	16)	74-5	D-25 dated 12 June 19	74-
186			a)	Shuttle Memo No. 10	E-74-27, "Navigation
187				Filter Covariance	Formulation Accuracy
188				Studies-Viewgraphs	Presented at JSC
					•

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190 June 1974.

1 .	U K ;s	7
2		TASK NO. SSTD-GN&C 25
3		
4	TITLE:	GN&C Sensor Procurement Specification Support
5		
6	OBJECTIVE:	Draper Laboratory will support the SD in the
7 -		review of selected GN&C system sensor procurement
8		specifications and make recommendations to the SD
9	•	for modifications, corrections or additional
10		information or requirements for such
11	to a first to the second secon	specifications.
12	•	
13	STATUS:	Completed
14		
15	SD ENGINEERING	
16	CONTACT:	D. Engels
17		
18	DI ENGINEERING	
19	CCNTACT:	G. Edmonds/R. McKern
20		
21	START/FINÍSH	
22	DATES:	16 April 1973 to 15 December 1973.
23		
24	REPORTS AND	
25	memos:	
26	•	1) 73-SD-66 dated 24 April 1973.
	<del>-</del>	COTD ONLO 25 ADD 74

SSTD GN&C-25 APR 74

2 <b>7</b>				a)	MIT/DL Memo to D. Engels and A. Zeitlin,
28	•			61	"Quick Review of Preliminary IMU S.O.W.
29					and IMU P.S.", dated 20 April 1973.
30					
31			. 2)	73-5	5D-77 dated 3 May 1973.
32				a)	23s Memo No. 77-73 (Rev. 1) "Questions
33	• •				in Support of Shuttle IMU Performance",
34		-			12 April 1973.
35					
36			3)	73-8	5D-94 dated 23 May 1973.
37		•	· ·	a)	235 Memo #88-73, "Review of Preliminary
38					SD IMU Procurement Specification".
39			4		
40			4)	73-9	SD-100 dated 7 June 1973.
41	•			a)	DG Memo No. 1827A, "Proposed Baseline
42	•			. •	Shuttle Display Generator Hardware
43					Instruction Set", 31 May 1973-Rev.1.
44	· · ·	•			
45			5)	73-5	SD-101 dated 8 June 1973.
46				a)	23A STS Memo No. 51-73, "Tolerances for
47		·			Pitot-Static Dynamic Pressure Measuring
48	•	۱ ا			System", 31 May 1973.
49					
50	<u> </u>			b)	23A STS Memo No. 52-73, BARO-Altimeter
51					Requirements for Entry, Approach and
52			-		Landing Navigation," 31 May 1973.
53					
					•

54	•	6)	73-S	D-107 dated 29 June 1973.
55			a)	DG Memo No. 1829, "Comparison of Display
56				Lengths As a Function of Display
5 <b>7</b>				Generator Instruction Set*, 20 June
58				1973.
59			•	
50		7)	73-S	D-112 dated 16 July 1973.
<b>5 1</b>		-	a)	23S Memo No. 93-73, Trip Report-NAR, 4-5
52			·	June 1973", dated 19 June 1973.
53				
54		8)	73 <b>-</b> 51	D-116 dated 26 July 1973.
55		-,	a)	23S Memo No. 110-73, "Response to NAR SD
<b>6</b> 6				IL 392-JBP-73-013, Reliability Models
57	•	. `		for Monitored Redundant Systems", 24
58	•			July 1973.
59	•		-	
70		9)	73-6	D-117 dated 26 July 1973.
		٠,		23S Memo No. 111-73, "Trip Report-North
71			a)	
12				American Rockwell Corp., July 16/20,
73				1973," 25 July 1973.
74	•	40.	<b>~</b> ^ ~.	. 400
15	<b>. . .</b>	10)		D-120 dated 31 July 1973.
76			a)	23S Memo No. 109-73, "The Shuttle and
77'	order (1995) The control of the con			Gimbal Flip", 23 July 1973.
18				
79	•	11)	73-S1	D-128 dated 13 August 1973.
30			a)	23S Memo No. 96-73, "Inflight Alignment
	•			<i>*</i>
			SS	TD GN&C-25 APR 74

81			Errors-Star Tracker", 26 June 1973.
82		b)	23S Memo No. 100-73, "Misalignment of
83			Star Tracker to NB", 6 July 1973,
84		c)	23S Memo No. 102-73, "Space Shuttle Star
85		·	Tracker Errors", 6 July 1973.
86		đ)	23S Memo No. 108-73, "Space Shuttle Star
87		•	Tracker Locations", 19 July 1973.
88	•	e)	23S Memo No. 112-73, "SN Uncertainty
89			Resulting from Sighting on Two Stars-A
90 ·			Comprehensive Perspective", 26 July
91		•	1973.
92		. f)	10J Memo No. 1-73, "The Uncertainty in
93		,	the NB to SM Transformations", 7 August
94			1973.
95		•	
96	•	12) 73-s	D-130 dated 14 August 1973.
97		a)	Intralab Memo No. 10J-4-73, "Results of
98		•	Recent Runs of Shuttle Crew Safety
99			Probability Program", 14 August 1973.
100	•		
101		13) 73-si	D-133 dated 21 August 1973.
102	1	a)	DG Memo No. 1827A, "Proposed Baseline
103			Shuttle Display Generator Hardware
104	<b>3</b>		Instruction Set", 31 May 1973 Rev. 1.
105	,	b)	DG Memo No. 1829, Comparison of Display
106			File Lengths as a Function of Display
107			Generator Instruction Set* 20 June 1973.

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_			
108	•	c)	DG Memo No. 1835, "Circuit and Packaging
109	•		Technology for Shuttle Display
110			Processor", 19 July 1973.
111		d)	DG Memo No. 1836, PMS Annunication
112		•	System", 30 July 1973.
113			
114		14) 73-9	D-135 dated 22 August 1973.
115		a).	Intralab Nemo No. 10J-2-73 Rev. 1.
116			"Coverage Consideration", 20 August
117	, · · · · · · · · · · · · · · · · · · ·	•	1973.
118 .		15) 73~s	D-138 dated 6 September 1973.
119		a)	Intralab Memo No. 10J-9-73 "Improved IMU
120			Model for Simulation of Kalman Filter in
121			IMU Alignment," 23 August 1973.
122		<b>b)</b>	
123			The state of the s
124			
125		-	Reference Units Fine Alignment with the
26	•		Optical Sensors", 29 August 1973.
27		16) 72 0	2.45
28			D-154 dated 19 October 1973.
	•	a)	Intralab Memorandum No. 10J-14-73, "IMU
29			Stable Member Misalignment Resulting
30			from Multiple Error Sources", 1 October
31		•	1973.
32		<b>b</b> )	Intralab Memorandum No. 10J-16-73,
33			"Possible In-Flight Calibration and/or
34			Test of Space Shuttle Star Trackers", 27
		•	

SSTD GN&C-25 APR 74

September 1973.

- 17) 73-SD-161 dated 14 November 1973.
  - a) Intralab Memo No. 10J-27-73, "Revision of Barometric Altitude Appendix of 235 Memo No. 72-67 Parameters for GNEC Subsystem Error Models", 7 November 1973.

1	U K :s	
. 2		TASK NO. SSTD-GN&C 26
3		• • • • • • • • • • • • • • • • • • •
4	TITLE:	Support of Intermetrics IMU FDI Test Plan Study
5		
6	OBJECTIVE:	Provide technical consultation to Intermetrics
7	•	Inc. as required to support their effort to SD for
8	·	the definition of a Test Plan for the Shuttle IMU
9		fault detection and isolation (PDI) verification.
10 ,	•	
11	STATUS:	Completed
12	•	
13	SD ENGINEERING	
14	CONTACT:	D. Engels
15	•	
16	DL ENGINEERING	
17	CONTACT:	R. McKern
18 . ,		
19	START/PINISH	
20	DATES:	23 April 1973 to 15 November 1973.
21	<b>`</b>	
22	REPORTS AND	
23	MEMOS:	
24	•	1) 73-SD-141 dated 12 September 1973.
25 -		a) Avionics Memo No. 73-17, "Multiple IMU
26		System Shuttle Baseline Testing at
	With the second of the second	NASA/MSFC", 25 July 1973.
	•• · · · · · · · · · · · · · · · · · ·	SSTD GN&C-26 11/73

TASK NO. SSTD-GNEC 27 Entry Guidance Evaluation Study This effort will be a joint design evaluation OBJECTIVE: . effort between SD, JSC, and CSDL. The objective will be to evaluate various entry guidance concepts with respect to performance accuracy, 10 GN&C computer requirements sensitivity to various mission and vehicle parameters, and other criteria 11 12 to be defined in the early part of this effort. 13 14. Terminated 15 16 SD ENGINEERING 17 CCNTACT: D. Engels 18 DL ENGINEERING 19 CONTACT: B. Kriegsman 20 21 START/FINISH . 22 2 July 1973 to 2 August 1974. DATES: 23 24 REPORTS AND 25 MEMOS: 26

27		73-	SD-126 dated 10 August 1973.
28		a)	23A STS Memo No. 69-73, "Entry Guidance
29			System Evaluation-Status Report", 3
30			August 1973.
31	•	•	
32	2)	73~	SD-152 dated 23 October 1973.
33		a)	10E STS Memo No. 77-73, "Shuttle Entry
34			Guidance Display & Crew Interface", 16
35			October 1973.
86			
3 <b>7</b> .		73-	SD-165 dated 7 December 1973.
8		a)	10E STS Memo No. 82-73, MEffect of SM
39			Alinement Errors on Navigation Errors
0			After Blackout-3B Entry Trajectory from
1			100 n. mi. Orbit", 15 November 1973.
2			
3	4)	73-9	SD-170 dated 11 December 1973.
4		a)	10E STS Hemo No. 76-73, Entry Guidance
5			System-Performance Evaluation, 12
6			October 1973.
7	5)	73-9	SD-174 dated 20 December 1973.
8	• •	a)	10E STS Memo No. 87-73, "Entry-Guidance-
9 .	· · · · · · · · · · · · · · · · · · ·	•	System performance EvaluationFinal
0			Data", 3 December 1973.
1		•	
2		b)	10E STS Memo No. 89-73, "Details of a
3			Reference Trajectory Guidance Concept

54			for Shuttle Entry and Transition", 14
55			December 1973.
56	·	•	
57		6)	73-SD-175 dated 26 December 1973.
58		•	a) 10E STS Memo No. 88-73, "Entry Guidance
59			Sytem Performance Comparisons", 14
60			December 1973.
61		•	
62	•	7)	74-SD-1 dated 2 January 1974.
63			a) 10E STS Memo No. 90-73, "Timing and
64			Sizing Studies of Three Shuttle Entry-
65			Guidance Algorithms", 18 December 1973.
66			

1		U K :s	
2			TASK NO. SSTD-GNEC 28
3 -			
4		TITLE:	GNEC 6 DOF Stability Evaluation Study
5		•	
6		OBJECTIVE:	This effort is to investigate the stability of the
7			FCS and guidance during the entry phase of the
8,		•	Shuttle landing. Existing simulations of the GN&C
9.			systems will be used and modified as required to
10 <sup>-</sup>	• .		support this effort.
11			
12		STATUS:	Completed
13			
14		SD ENGINEERING	
15		CCNTACT:	D. Engels
16			
17		DL ENGINEERING	
18		CONTACT:	G. Levine/D. Fraser
19			•
20		START/FINISH	
21.		DATES:	15 June 1973 to 15 November 1973.
22			
23		REPORTS AND	
24		memos:	<b>1</b>
25			
26			1) 74-SD-2 dated 3 January 1974.

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a) 10E STS Memo No. 91-73, "Stability
Evaluation of Shuttle Entry Guidance and
Control Interaction", 27 December 1973.

1 .	U K :s	
2		TASK NO. SSTD-GN&C 29
3		
<b>u</b> ,	TITLE:	One-Way Doppler Navigation Performance for Various
5 ·		Mission Phases.
6 .		
7	OBJECTIVE:	This effort is an extension of SSTD-GN&C 10 (Use
8 .		of Transponder on Ground Tracking for IMU
9		Calibration and Alignment during Boost and
10		Insertion) to include one-way doppler data for
11		Shuttle navigation during all mission phases.
12		
13	STATUS:	Completed
14		
15	SD ENGINEERING	
16	CONTACT:	D. Engels
17		
18	DL ENGINEERING	
19	CCNTACT:	B. Kriegsman/G. Muller
20		
21	START/FINISH	
22	DATES:	4 June 1973 to 10 February 1974.
23	j.	·
24	REPORTS AND	•
25	MEMOS:	· · · · · · · · · · · · · · · · · · ·
	,	

## SSTD GN&C-29 APR 74

1) 73-SD-102 dated 8 June 1973.

27		a)	23A STS Memo No. 50-73, "Boost Phase
28			Navigation With One-way Doppler and IMU
29			Measurements", 29 May 1973.
30		-	
31	2)	73-SD	0-106 dated 26 June 1973.
3 <sub>2</sub>		a)	CSDL Memo to M. Madden from E. Muller,
33		•	"One-Way Doppler Model", 26 June 1973.
34	•		
35	3)	73-SD	)-121 dated 1 August 1973.
36		a)	23A STS Memo No. 65-73, "Boost-Phase
37	•		Navigation Studies with One-Way Doppler
38			and IMU Data-New Sensors and Acquistion
39			Models", 1 August 1973.
40			
41	4)	73-SD	9-134 dated 21 August 1973.
42		a)	Data transmitted to R. Loeliger, July
43			27, 1973.
4.4		b)	Data transmitted to R. Loeliger, August
45			1, 1973.
46		c)	Memo to R. Loeliger from E. Muller dated
47			3 August 1973, "Doppler Study (TD No.
48			29) - Ground Station Performance".
4 9		đ)	Data transmitted to R. Loeliger, August
			7, 1973.
50			
51	5)	73-sp	0-136 dated 5 September 1973.
	5)		0-136 dated 5 September 1973.  CSDL Memo to R. Loeliger from E. Muller/

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58

. 59 6) · 73-SD-146 dated 20 September 1973.

a) 10E STS Memo No. 72-73, "Entry-through-Landing Navigation with One-Way Doppler and Radar Altimeter," 13 September 1973.

1 .	U K :s	
2		TASK NO. SSTD-GNEC 30
3		
4	TITLE:	Appendix to the Requirement Formulation Document
5		(RFD)
6		
7	OBJECTIVE:	The appendix to the Requirements Formulation
8 '		Document is to contain the algorithms that define
9		the GNEC equations for the Space Shuttle. It is
10 .		requested that CSDL determine procedures,
11		quidelines and checklists that will serve as an
12		aid to the documentation and verification of the
13	•	RFD.
14		
15	STATUS:	Completed
16		
17	SD ENGINEERING	
18	CONTACT:	L. McGaha
19		
20	DL ENGINEERING	
21	CONTACT	M. Hamilton
22 -	: :.	
23	START/FINISH	
24	DATES:	1 August 1973 to 14 September 1973.
25		
26	REPORTS AND	

27	MEMOS:"	•	
28		1)	73-SD-131 dated 17 August 1973.
29		·	a) CSDL Preliminary Report E-2793, "Higher
30			Order Software Requirements", August
31		•	1973.
32			
33		2)	73-SD-144 dated 14 September 1973.
34			a) CSDL Report E-2793, "Higher Order
35			Software Requirements", August 1973.
	-		

1 .	u K :s	
2	•	TASK NO. SSTD-GN&C 31
3		
4	TITLE:	GN&C System Fault Detection, Isolation and
5.		Recovery (FDIR) Study
6		
7	OBJECTIVE:	1) Review crew safety and mission success
8		reliability requirements and determine the
9	•	resulting redundancy management requirements on
10		the GN&C System FDIR.
11		
12		2) Conduct an initial evaluation of possible FDIR
13		concepts for the overall GNEC system level. The
14		current GN&C baseline and its operating modes will.
15		be used as the basis of this study.
16		
17		3) Develop a preliminary FDIR design outline for
18		the overall GNEC system.
19		
20	STATUS:	Complete
21		
22	SD ENGINEERING	
23	CONTACT:	R. Ellison
24		
25	DL ENGINEERING	
26	CONTACT:	G. Edmonds
•		

27.			
28	START/FINISH		
29	DATES: 27	August	1973 to 5 November 1973.
30			
31	REPORTS AND		
32	memos:		
33	1)	73-SI	D-140 dated 7 September 1973.
34		a)	Introlab Memo No. 10J-8-73, "Augmented
35			Coverage Matrix", 27 August 1973.
36			
37		b)	Intralab Memo No. 10J-11-73, "Crew
38			Safety Probability Impact of Combining
<b>39</b> .			Data from all Redundant Elements rather
40			than Designating a Prime Element", 31
41			August 1973.
42	2)	73-si	D-155 dated 30 October 1973.
43		a)	Digital Development Memo No. 773, Rev.
44			1, "The Effect of Shuttle Flight
45			Computer Failures", October 5, 1973.
46		b)	Introalab Memorandum No. 10J-20-73,
47			"Proposed Combined Optics IMU FDI for
48	\$		Costing Flight", 15 October 1973.
49			
50	3)	73-S1	0-157 dated 8 November 1973.
51		a)	CSDL Report R-733, "Space Avionics-A
52			Redundant INU On-Board Checkout and
53			Redundancy Management System", September

55	•
56	
57	
58	
59	
60	
61	

54

b) ISS Memo No. 73-112, "Multiple INU System Baseline Testing at NASA/MSFC,"
July 1973.

- 4) 73-SD-158 dated 8 November 1973.
  - a) CSDL Report T-560, "An Adaptive Technique for a Redundant--Sensor Navigation System", February 1973.

U K :s

TASK NO. SSTD-GNEC 32

J

TITLE

Boost Aborts-Powered Flight Guidance Phase

define the requisite guidance policies.

6

7

OBJECTIVE:

OPPECITAR:

CSDL is requested to support Rockwell in the definition of Shuttle Boost Abort modes - in particular once around modes and the powered phase of RTLS modes. Interaction with SD in-house trajectory shaping/vehicle constraint definition efforts are requested in order to meaningfully

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CSDL will perform studies on the powered portion of once around and RTLS aborts including off-nominal vehicle effects. Powered abort quidance policies will be integrated with nominal policies to provide a unified concept. CSDL will participate in design reviews at JSC and on-site study efforts at Rockwell as requested.

Completed

SD ENGINEERING

STATUS:

CONTACT:

J. Hill/D. Engels

27	DL ENGINEERING		
28	CONTACT:	T. Brand	
29	START/FINISH	•	
30	DATES:	15 October 1973 to 1 February 1974.	
31,			
32	REPORTS AND		
33	MENOS:		
	•	·	

1	U K :s	
2		TASK NO. SSTD-GNEC 33
3		
4	TITLE:	Software Requirements Documentation Support
5		
6	OBJECTIVE:	Assist Rockwell in the review of Functional
7	•	Software Documentation and suggest formats and
8		organization for such documentation. CSDL will
9	•	participate in the generation of functional
10		requirements and algorithm selection and
11		specification under Rockwell direction for
12		inclusion in the functional software requirements
13		documents. This effort will include a review of
		,
14		possible documentation organization consistent
14 15		possible documentation organization consistent with the software program structuring concepts
14 15 16		possible documentation organization consistent with the software program structuring concepts
14 15 16 17	STATUS:	,
14 15 16 17	STATUS:	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.
14 15 16 17 18	STATUS: SD ENGINEERING	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.
13 14 15 16 17 18 19 20		possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.
14 15 16 17 18 19 20	SD ENGINEERING	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.  Completed
14 15 16 17 18 19 20 21	SD ENGINEERING	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.  Completed
14 15 16 17 18 19 20 21 22	SD ENGINEERING	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.  Completed
14 15 16 17 18	SD ENGINEERING CONTACT: ( DL ENGINEERING	possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.  Completed  L. McGaha

27	DATES:	<b>1</b> 5	October 1973 to 20 February 1974.
28			
29	REPORTS AND		
30	MEMOS:		
31		1)	73-SD-167 dated 10 December 1973.
32			a) CSDL Memo to L. McGaha from G. Levine,
33			"Review of Software Requirements
34			Document Book I Volume III, 2 November
35			1973 Issue", dated 6 December 1973.
36			
37		2)	73-SD-171 dated 11 December 1973.
38			a) CSDL Report No. P-017, "An Example of
39		,	Algorithm Comparison Using Higher Order
40			Software Criteria", 6 December 1973.
41			b) CSDL Report No. P-019, A Discussion of
42			Higher Order Software Concepts As They
43			Apply to Functional Requirements and
44			Specifications, 5 December 1973.
45.		•	· · · · · · · · · · · · · · · · · · ·
46	•	3)	74-SD-8 dated 5 March 1974.
47		-,	a) CSDL Document C-4034, Space Shuttle GN&C
48	· · · · · · · · · · · · · · · · · · ·		Equation Document No. 25 Rev. 1, Conic
49			State Extropolation", February 1974.
72	<b>.</b>		

1	U K :s	
2		TASK NO. SSTD-GN&C 34
· 3		
4	TITLE:	Deorbit Targeting
5		
6	OBJECTIVE:	Perform studies aimed at defining the shuttle
7		deorbit targeting algorithms. Studies shall
8		include performance in face of off-nominal
9		parameters, system failures, (i.e. OMS one engine
10 -	•	shutdown), vehicle and subsystem constraints.
11		
12	STATUS:	Cancelled
13		
14	SD ENGINEERING	
15	CONTACT:	L. McGaha
16		
17	DL ENGINEERING	
18	CONTACT:	T. Brand/W. Tempelman
19		
20	START/FINISH	
21	DATES:	15 October 1973 to 15 February 1974.
22		
23	REPORTS AND	
24	MEMOS:	
25		1) 73-SD-153 dated 29 October 1973.
26		a) 10E STS Memo No. 78-73, "Single and

SSTD GN&C-34 APR 74

Double Manuever Deorbits from Elliptical Orbits", 18 October 1973.

- 2) 73-SD-160 dated 12 November 1973.
  - a) 10E STS Memo No. 81-73, "Fuel Penalties
    Associated with the Use of Phasing
    Orgit", 5 November 1973.
- 3) 73-SD-168 dated 10 December 1973.
  - a) 10E STS Memo No. 86-73, "Using of a Phasing Orbit to Mitigate Reentry Conditions in the Deorbit Problem", 3
    December 1973.
- 4) 74-SD-10 dated 13 March 1974.
  - a) Shuttle Memo No. 10E-74-13, "Analytical Determination of the Conic Trajectory Which Satisfies the Deorbit Entry Interface Constraint," 4 March 1974.

•	U K :s		
2		TASK N	D. SSTD-GNEC 35
3			•
4	TITLE:	Adaption of TAEM and AUTOLAND Guidas	nce to HPT
	1 4 1 11 11 4	Addition of them and autotran outles	ice to art
5			•
6	OBJECTIVE:	1) Identify HFT mission and traject	ory.
7		\$ *** 	
8		2) Identify vehicle/trajectory di	fferences from
9		"conventional" TAEM/A.L.	
0	14.54 m		
1		3) Identify TAEM/A.L. test/verifica	tion data to be
2		performed during HFT.	•
3			
4	**	4) Analyze effects of uncertain	inties/failures
5		during HFT and possible remedies.	
6		darang mil was possible lemedicas	•
	anamus -	7	
<b>7</b>	STATUS:	Discontinued	
8	•		•
9	SD ENGINEERING		
0	CONTACT:		
1	A		
2	DL ENGINEERING		
3	CCNTACT:	A. Elias	
4			•
5	START/FINISH		
6 .	DATES:	15 January 1974 to 2 August 1974	
•			
			$\label{eq:continuous} \mathcal{L}_{\mathcal{L}} = \mathcal{L}_{\mathcal{L}} = \mathcal{L}_{\mathcal{L}} = \mathcal{L}_{\mathcal{L}}$

UK:

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TASK NO. SSTD-GN&C 36

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TITLE:

Study the Feasibility of Extending TAEN to 130,000 ft.

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OBJECTIVE:

Study the feasibility and determine the advantages and disadvantages associated with extending the baseline TAEM guidance concept to be initiated at an altitude of 130,000 feet. The concept which would be extended to the higher altitude is to use Energy/Weight (E/W) versus Range (P) for control of energy via bank reversals. A ground track predictor would be used which is suitable for predicting the ground track to runway threshold and applicable for the proposed flight phase. The heading control during this phase would be to quide the orbiter to tangency to the heading alignment circle. The study would require evolving any essential additional algorithms necessary to operate over the proposed flight range, and to properly interface with the entry quidance system.

25

26

The potential advantage of this method over

the current phase Four (4) entry guidance is that it would have a more natural interface with the baseline TAEM guidance system below 70,000 feet. Hence, it would enable the guidance system below 70,000 feet to more easily satisfy its design objectives. The task would include developing and evaluating the pilot displays which would presumably be similar to those currently used for TAEM guidance below an altitude of 70,000 feet.

The study should include an investigation of the feasibility and limitations to making a change at 130,000 ft. Altitude to the landing direction. This would require the necessary retargeting and providing correction for navigation errors existing after blackout in the presence fo the most adverse design winds. The lowest altitude shall be determined for which a change in landing direction can safely be made in the absence of winds and with design winds.

STATUS:

Completed

SD ENGINEERING

51 CONTACT:

H. Ehler

DL ENGINEERING

<b>.</b>	CONTACT.	We Frida
55	, ·	
56	START/FINISH	
57	DATES:	15 March 1974 to 2 August 1974.
58		
59	REPORTS AND	
60	memos:	1) 74-SD-32 dated 15 August 1974.
61	1	a) CSDL Shuttle Memo No. 10E-74-42, "Early TAEM
62	,	Initiation", 29 July 1974.
63	•	

1	U K :s	
2		TASK NO. SSTD GN&C-37
3		
4	TITLE:	Support of Powered Flight Guidance Working Group
5		
б	OBJECTIVE:	Provide engineering analysis and simulation
7		support needed by the Powered Flight Guidance
8	•	Working Group in order to establish a unified set
9		of baseline guidance algorithms for all
10,	•	exoatmospheric maneuvers; i.e. ascent to orbit,
11		boost abort, rendezvous, orbit shaping, and
12	·	deorbit.
13		
14	STATUS:	Terminated
15		
16	SD ENGINEERING	
17	CCNTACT:	D. Engels
18		
19	DL ENGINEERING	
20	CCNTACT:	T. Brand /
21	•	
22	START/FINISH	
23	DAŢES:	1 FEBRUARY 1974 TO 2 AUGUST 1974.
24		
25	REPORTS AND	
26	MEMOS:	1) 74-SD-19 dated 30 April 1974.

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27	a)	CSDL Report C-4109, "Space Shuttle GEN
28	٠	Equation Document No. 24 Revision 1, Unified
29		Powered Flight Guidance, "April 1974.
30		3
31		2) 74-SD-22 dated 14 May 1974.
32	a)	CSDL Shuttle Hemo No. 10E-74-21, "Shuttle
33		Deorbit Burn Performance for T/W Different
34		from Targeted Value", 4 May 1974.
35		3) 74-SD-27 dated 16 July 1974.
36	a)	CSDL Shuttle Memo No. 10E-74-29, "RTLS Fuel
37 .		Depletion Throttle Algorithm for the Powered
38		Explicit Guidance Program," 11 June 1974.
39	b)	CSDL Document No. C-4108, "Space Shuttle G&N
40		Equation Document No. 24, Rev. 2, Unified
41		Powered Flight," June 1974.
42		
43		4) 74-50-30 dated 1 August 1974.
44	a)	CSDL Shuttle Memo No. 10E-74-31, "Simplified
45		RTLS Fuel Depletion Throttle Algorithm for
46		PEG," 27 June 1974.
47	b)	CSDL Shuttle Memo No. 10E-74-38, "Powered
48		Flight Guidance Compensation for Non-
49	•	Keplerian Gravity Effects During Deorbit," 17
50		July 1974.
51		•
52		5) 74-SD-31 dated 13 August 1974.
53	a)	CSDL Shuttle Memo No. 10E-74-41, "Closed Form

# SSTD GN&C-37 AUG 74

55	
56	
57	,
58	
59	

60

54

Conic Required Velocity for Deorbit Mode," 5
August 1974.

- 6) 74-SD-33 dated 15 August 1974.
- a) CSDL Shuttle Memo No. 10E-74-40, "Used of the Powered Explicit Guidance Program for Orbit Shaping," 8 August 1974.

1	U K :s	. '
2		TASK NO. SSTD GNEC-38
3		
4	TITLE:	Assessment of Navigation Sensor Errors on Shuttle
5		PBO Footprint Capability
6	•	
. 7	OBJECTIVE:	Using an agreed upon Shuttle Entry Trajectory
8		assess the footprint sensitivity to deviation in
9		vehicle position and velocity.
10		
11		Formulate correct statistical methods for
12		assessing platform component failures at PBO
13		footprint.
14		<b>,</b>
15		Using existing data where available, determine
16	,	significant platform parameters and trajectory
17		phases to be investigated.
18		
19		Using the data from steps 1-3 above, determine
20		allowable margins for platform errors exceeding 3
21	· • • • • • • • • • • • • • • • • • • •	siqma.
22		
23		Using a trajectory program with coupled GEN,
24		determine curves of failure magnitude vs. the
25	*	required time to detect and switch with the
26		failure. These curves are determined by comparing

27		magn.	itude	of observed	trajec	tory error	against	the
28		allo	wable	footprint m	argin de	etermined	in Step	1.
29								
30	STATUS:	Term	inate	d ,				
31	·				•			
32 .	SD ENGINEERING				. :		. ,	
33	CONTACT:	A. Ma	adni	,				
34					4			
35	DL ENGINEERING				•	٠.	٠	••
36	CONTACT:	G. L	evine	/B. Kriegsma	n <sub>.</sub>			
37								*
38	START/FINISH	•		•				
39	DATES:	1 May	7 197	4 to 2 August	t 1974	,		
40						•		
41	REPORTS AND			•		•		
42	memos:		•					•
43		1)	74-s	D-23 dated 3°	1 May 19	74.		
44			a)	CSDL Shuttl	le Memo	No. 10E-	74-26,	"IMU
45		ű.		FDI Require	ements f	or Entry-	-and-Lan	ding
46				Phase, Prel	liminary	Results'	, 30	May
47				1974.				
48	`		•					•
49	• •	2)	74-S	D-28 dated 16	6 July 1	974.	*	
50	مني		a)	CSDL Shuttl	le Memo	No. 10E-74	-32, "E	ntry
51	•	,		and Landing	Navigat	ion Analys	sis", 2	July
52				1974.			•	
53	•	3)	74-s	D-29 dated 19	9 July il	974.		

SSTD GN&C -38 AUG 74

a) CSDL Shuttle Memo No. 10E-74-37, "Post Blackout Navigation Errors as a Result of a Temporary IMU Failure During Period from Deorbit to End of Blackout", 16 July 1974.

1	u K :s	
2		TASK NO. SSTD-PMS 1.0
3	·	
4	TITLE	Inflight PMS Role
5		
6	OBJECTIVE:	1) Define the role of the PMS in orbiter subsystem
7		management considering mission requirements &
8		vehicle requirements.
.9		
10		
11		2) Review the MCC-H functions which are presently
12	,	done for Apollo. Identify the candidate PMS
13		functions as they relate to configuration,
14	•	criticality and redundancy for subsystem
15		management.
16	STATUS:	Complete
17	•	
18	SD. ENGINEERING	
19	CONTACT: -	R. Minor
20		
21	DL ENGINEERING	
22	CONTACT:	G. Silver
23		
24	START/FINISH	
25	DATES:	13 November 1972 to 19 April 1973.

26

21	REPORTS AND	
28	MEMOS:	
29		
30		1) 73-SD-3 dated 8 January 1973.
31	•	a) "Submittal of Preliminary PMS Study
32		Report-PMS 1.1," 8 January 1973.
33	•	
34		2) 73-SD-5 dated 10 January 1973.
35		a) "Submittal of Preliminary SSTD-PMS-1.2
36		REPORT", 10 January 1973.
37 .		
38	•	3) 73-SD-26 dated 8 March 1973.
39	,	a) "Submittal of Update SSTD-PNS-1.2
40	· ·	REPORT", 8 MARCH 1973.
41		
42	•	4) 73-SD-45 dated 9 March 1973.
43		a) "Submittal of Update Report for PMS 1.1
<b>त</b> क	-	Task", 9 March 1973.

1	UK:s	
2	•	TASK NO. SSTD-PMS 2.0
3		
. 4	TITLE:	PMS/GN&C Relationship
5	·	
6	OBJECTIVE:	
7		1. Develop candidate relationship between GNSC $\&$
8		PMS
,9		
10	•	2. Analyze the total GN&C tasks to be performed
11		and develop candidate relationships between
12		the two subsystems.
13		
14	STATUS:	Complete
15		
16	SD ENGINEERING	
17	CONTACT:	R. Minor
18		
19	DL ENGINEERING	
20	CONTACT:	G. Silver
21	,	
22	START/FINISH	
23	DATES:	22 November 1972 to 19 April 1973.
24		
25	, REFORTS AND	
26	MEMOS:	

27		
28	1)	73-5D-9 dated 1 February 1973.
29		a) "Submittal of Preliminary PMS 2.0 Task
30	•	Report", dated 1 February 1973.
<b>31</b>		
32	2)	27-SD-54 dated 26 March 1973.
33		a) "Submittal of Update Report PMS 2.0
34		Task", dated 26 March 1973.
		, •

1	U K :s	
2		TASK NO. SSTD-PMS 3.0
3		
4	TITLE:	PMS Phasing Alternatives
5		
6	OBJECTIVE:	Using data developed in Tasks 1 & 2, develop PNS
7		alternatives
8		·
9 .	STATUS:	Completed
10 .	•	·
11	SD ENGINEERING	-
12	CONTACT:	R. Minor
13	•	
14	DI ENGINEERING	
15	CONTACT:	G. Silver/Ţ. Lawton
16		
17	START/FINISH	•
18	DATES:	2 January 1973 to 2 April 1973
19		·
20	REPORTS AND	
21	menos: `	
22		1) 73-SD-33 dated 21 February 1973.
23		a) "SSTD-PMS 3.0, Preliminary Report
24	•	Submittal", dated 21 February 1973.

U K :s 2 TASK NO. SSTD-PMS 4.0 3 TITLE: Definition of Functional Software Concept for the 5 PMS Function 7 OBJECTIVE: Define a software concept for the PMS (non-GNC) 8 using the PMS concept defined in previous SSTD-PMS 9 tasks 1 thru 3. Consider and work with the HAL 10 definition and evaluation teams to define needed 11 HAL language statements which might be PMS unique. 12 13 Preliminary output shall include a general 14 description of the concept and general flow diagrams in a detail sufficient for the subsystem 15 16 designers and software teams to understand the 17 concept. 18 19 typdate outputs shall include more detailed 20 descriptions of the concept and flow diagram 21 blocks, as well as more detailed flow diagrams and 22 descriptions. 23 24 A report on HAL language suitably shall also 25 be generated after proper consultation with the

HAL team.

26

SSTD PMS-4 11/73

27		
28		NAAD/RI shall support this task by providing
29	•	subsystem functional path definitions and related
30		measurement priority designations.
31		
32	STATUS:	Completed
33		
34	SD ENGINEERING	
35	CONTACT:	W. Harris
36		
37	DL ENGINEERING	
38	CONTACT:	G. Silver
` 39	•	
40	START/FINISH	
41	DATE:	6 April 1973 to 27 August 1973
42		
43	REPORTS AND	
44	MENOS:	
45		1) 73-SD-96 dated 29 May 1973.
46		a) Submittal of Initial Report on PMS 4.0.
47		
48	`	2) 73-SD-111 dated 16 July 1973.
49		a) Submittal of Update Report of PMS Task
50	÷	4.0.

1

26

U K :s

TASK NO. SSTD-PMS 5.0

Define a Possible PMS Annunciation Concept

preliminary form a display an annunciator concept for PMS which minimizes crew actions to identify and retrieve the high level information needed to aid in subsystem management applicable to the PMS monitored subsystems.

Preliminary outputs shall be a report with sketches and general flow diagrams in sufficient detail for subsystem designers and software teams

Update outputs shall further define the concept, considering the comments of the NAAD technical reviewers and describe the methods of decoding the PMS table information from PMS task 4.0 for activation of the indicators.

NAAD/NI support of this task shall include comments and unique display requirements as well as coordination with the subsystem design teams.

SSTD PMS-5 11/73

27	STATUS:	Completed
28		
29	SD ENGINEERING	
30	CCNTACT:	W. Harris
31		
32	DL ENGINEERING	
33	CONTACT:	G. Silver/K. Goodwin
34		
35	START/FINISH	
36	DATES:	7 May 1973 to 27 August 1973.
37 '		
38	REPORTS AND	
39	MEMOS:	
40		1) 73-SD-104 dated 18 June 1973.
41		a) Submittal of Initial Report of PMS Task
42		5.0.
43		
44	•	2) 73-SD-119 dated 31 July 1973.
45		a) Submittal of Update Report of PMS Task
46	•	5.0.

,	U K IS	•
2		TASK NO. SSTD-PMS 6.0
3		<b>→</b>
đ	TITLE:	Continuation of SSTD PMS 1.1, 1.2, 2.0 and 3.0
,5		
6	OBJECTIVE:	The tasks previously worked as PMS 1.1, 1.2, 2.0,
7		and 3.0 will be continued on a low level as
8	•	required basis.
9	,	
10	6	The effort will include, for example, further
11	•	definitions of the consumables management and
12		trend analysis capabilities.
13		
14	•	Effort is expected to be dependent upon
15		configuration changes, and/or requirements updates
16		as defined by NAAD/PI.
17		
18	STATUS:	Completed
19		
20	SD ENGINEERING	·
21	CONTACT:	W. Harris
22		
23	DL ENGINEERING	•
24	CONTACT:	G. Silver
25	•	
26	START/FINISH	

27	DATES:	6 April 1973 to 7 September, 1973.		
28				
29,	REPORTS AND			
30	MEMOS:	•		
31		1)	73-SD-137 dated 31 August 1973.	
32			a) Submittal of Consumables Management	
33	•		Portion of PMS Task 6.0.	
34				
35		2)	73-SD-139 dated 7 September 1973.	
36			a) Submittal of Update Report PMS Task 3.0.	

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