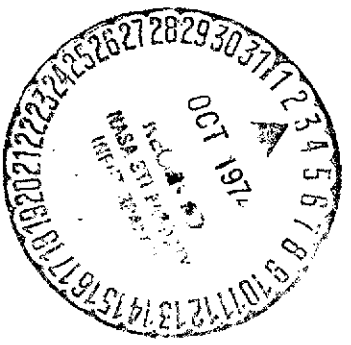
FINAL REPORT ON
NASA/JSC CONTRACT NO. NAS9-13207

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

PERIOD: 1 November 1972 to 31 August 1974.

23 August 1974.



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: CSDL 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:

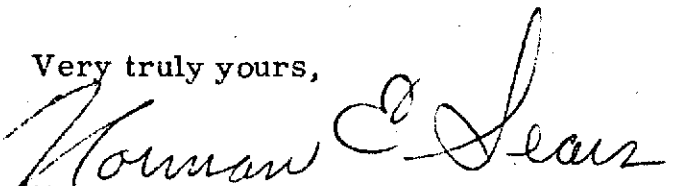
Attached is the CSDL Final Report for the subject contract. This report is being submitted in accordance with reference 1 above.

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

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74-SD-34

FINAL REPORT

ON

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

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U K :s

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C = Completed Task

D = Discontinued, do to lack of data

T = Terminated under this contract, subject to continuation under Rockwell SD Purchase Order

W = Withdrawn Task

U K :s

TASK NO. SSTD-GN&C 1

TITLE: Review Baseline GN&C System

OBJECTIVE: Perform a review of current GN&C baseline system identifying problem areas; implied constraints; effects on costs, schedule and reliability. Provide possible changes and additions with rationale, justification or basis for same. Draw on flight experience of previous operational system where appropriate. Look specifically at reliability, failure detection coverage and computer sizing.

STATUS: Completed - (Redirected under GN&C - 12 & 17)

SD ENGINEERING CONTACT: M. Campbell

DI ENGINEERING CONTACT: N. Sears

START/FINISH DATES: 1 November 1972 to 28 February 1973

REPORTS AND MEMOS:

1) 72-SD-2, dated 11 December 1972.
   a) MIT/DL Memo, "Recent Crew Safety Probability Studies," 4, December 1972.

2) 72-SD-3, dated 12 December 1972.
   a) Shuttle Software Memo No. 50 Rev 1, "Sizing Estimates for Primary and Backup GN&C Software," 30 November 1972.

3) 72-SD-4 dated 8 December 1972.
   a) DD Memo No. 715, "Dissimilar vs Similar GNCS Back-up Pros and Cons Summary," 29 November 1972.

4) 72-SD-5, dated 11 December 1972, "Status Review of SSTD-GN&C-1."

5) 72-SD-14, dated 28 December 1972.
   a) DD Memo No. 709 Rev. 1, "Computer System Reliability for the Shuttle," 8 December 1972.

6) 72-SD-15, dated 27 December 1972.
   a) Shuttle Software Memo No. 50 Rev 2, "Sizing Estimates for Primary and Backup

GN&C Software," 19 December 1972.

7) 73-SD-4 dated 8 January 1973.

   a) "Lightning Protection Study," Excerpted from Task 28-S, Vol. 4.

   b) "Enforcement of Single Computer Type: Apollo Experience," Excerpted from Task 28-S, Vol. 4.

8) 73-SD-10 dated 6 February 1973.

   a) "Dedicated Wire vs Data Bus," Excerpted from Task 28-S Vol. 2.

   b) "Redundancy Management Concepts for the Assumed DCDS," Excerpted from Task 28-S Vol 4.

   c) "Improving Coverage (Error Detection and Isolation) Over That Afforded by BITE," Excerpted from Task 28-S Vol. 4.

   d) "Built-In Tests", Excerpted from Task 28-S Vol. 4.

   e) "Consistency Tests," Excerpted from Task 28-S Vol. 4.

   f) "The Reliability Impact of Mission Abort Strategies On Redundant Flight Computer Systems," 1973 IEE Paper by R. Filene and W. Daly, December 1972.

9) 73-SD-13, dated 9 February 1973-

a) January 1973 Review Presentation Material for SSTD GN&C-1.

10) 73-SD-25, dated 15 Febraury 1973.

a) "Shuttle Avionics Computer System Studies," Task 28-S Vol. 4 December 1972.

11) 73-SD-40, dated 5 March 1973.

a) E-2529, "STS Data Management System Design (Task 2)," June 1970.

b) "AGC/SHUTTLE Studies Report," December 1970.

12) 73-SD-41, dated 6 March 1973.

a) DD Memo No. 696, "The Mechanics of Bi-Phase Coding on a Data Bus," 12 September 1972.

13) 73-SD-52, dated 20 March 1973.

a) "Reconfiguration Control," Excerpted from Task 28-S, Vol.4.

b) DD Memo No. 726 Rev. 1, "A Fault Tolerant Reconfiguration Control Unit" (Mod I), 9 February 1973.

c) DD Memo No. 733 Rev. 1, "A Fault

Tolerant Reconfiguration Control Unit" (Mod II), 23 February 1973.

d) DD Memo No. 735, "A Fault Tolerant Reconfiguration Control Unit" (Mod III), 9 March 1973.

e) DD Memo No. 729 Rev. 1, "Time Varying Coverage", 23 February 1973.

f) DD Memo No. 737, "Reliability of Voting Systems," 12 March 1973.

14) 73-SD-60 dated 10 April 1973.

a) DD Memo No. 730 Rev. 3, "Thoughts on the Meaning and Application of Coverage", 9 April 1973.

b) DD Memo No. 746, "Vote with 5 Computers," 10 April 1973.

15) 73-SD-109 dated 5 July 1973.

a) "Shuttle Avionics Computer System Studies (Task 28-S) Volume 5".

U K :s

TASK NO. SSTD-GN&C 2

TITLE: Computer Compatibility Study

OBJECTIVE: Prepare a document describing the computer executive and coding system at MIT/DL to the extent required to: a) determine feasibility of adapting MIT/DL computer programs to run on SD 360 computers and vice versa, and b) to estimate the magnitude of the effort involved.

STATUS: Completed

SD ENGINEERING CONTACT: M. Campbell

DL ENGINEERING CONTACT: R. Russell

START/FINISH DATES: 1 November 1972 to 12 December 1972

REPORTS AND MEMOS:

1) 72-SD-7 dated 12 December 1972.

a) "Computer Compatibility with North American Rockwell".

2) 73-SD-12 dated 9 February 1973.

a) "Transmittal of the MIT/DL MAC Compiler Program".

3) 73-SD-36 dated 26 February 1973.

a) "Transmittal of MIT/DL Users Guide to MAC 360".

4) 73-SD-110 dated 3 July 1973.

a) "Transmittal of CSDL MAC Compiler Programs".

U K :S

TASK NO. SSTD-GN&C 3

TITLE:	GN&C System Functional and Performance Requirements Definition
OBJECTIVE:	Perform studies and analysis to define GN&C functional and performance requirements for all flight phases except for those aspects which are pure control functions.
STATUS:	Completed
SD ENGINEERING CONTACT:	M. Campbell
DL ENGINEERING CONTACT:	G. Edmonds
START/FINISH DATES:	1 November 1972 to 1 March 1973
REPORTS AND MEMOS:	1) 72-SD-6 dated 12 December 1972.

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 Velocity-Indexed 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, "DME Error Models

Used in Entry Navigation Analysis", dated 19 May 1971.

i) 23A STS Memo #44-71, "Entry and Landing Navigation for SSV Orbiter Using IMU and Precision Ranging System", dated 9 September 1971.

j) 23A STS Memo #49-71 Rev. 1, "Entry and Landing Navigation Study for SSV Orbiter Using PRS Navaids", dated 4 October 1971.

k) 23A STS Memo #11-72, "Entry and Terminal Phase Navigation for SSV Orbiter Using MLS as AILS and VOR/DME", dated 16 February 1972.

l) 23A STS Memo #41-72, "Navigation Errors on Various Shuttle Approach Trajectories", dated 14 June 1972.

2) 72-SD-9 dated 20 December 1972.

a) MAC Program Used to Compute TPS Weight dated 19 December 1972.

b) 23A STS Memo #62-72, "Insertion Errors for SSV Orbiter On Once-Around SPO Trajectory", dated 11 December 1972.

c) 23A STS Memo #64-72, "IMU Error Sensitivities for Normal Entry from 270

n. mi. Earth Orbit", dated 19 December 1972.

3) 72-SD-11 dated 21 December 1972.

a) 23A STS Memo #24-70, "Report on Orbit Navigation Studies for SSV", dated July 1970.

b) Memo from G. Muller (MIT/DL) to D. Engels (NR) dated 20 December 1972.

4) 72-SD-16 dated 28 December 1972.

a) 23A STS Memo #52-72, "Shuttle UV Horizon Sensing Orbit Navigation Performance Part I: Effect of W Matrix Reinitialization Frequency and Values", dated 13 November 1972.

b) 23A STS Memo #60-72 "Shuttle UV Horizon Sensing Orbit Navigation Performance Part II: Horizon Sighting Direction and Frequency Requirements", dated 15 December 1972.

c) Space Shuttle GN&C Equation Document #21, "Shuttle Unified Navigation Filter", dated 21 November 1972.

5) 72-SD-17 dated 29 December 1972.

a) Memo from G. Muller MIT/DL to M. Madden (NR) dated 28 December 1972.

6) 72-SD-18 dated 29 December 1972.

a) 23A STS Memo #67-72, "Covariance of Deviation in Flight Path Angle at Entry Interface", dated 22 December 1972.

7) 73-SD-2 dated 2 February 1973.

a) 23A STS Memo #3-73, "Covariance Matrix for IMU Alignment Errors and Correlation Matrix between Alignment and State Vector Estimation Errors", dated 3 January 1973.

8) 73-SD-11 dated 8 February 1973.

a) MIT/DL Memo, "Once-Around SPO Trajectory Data for NR", dated 6 February 1973.

9) 73-SD-14 dated 2 February 1973.

a) Transmittal of "January 1973 Review Presentation Material for SSTD GN&C-3,4&7."

10) 73-SD-20 dated 2 February 1973.

a) 23A STS Memo No. 68-72, "W-Matrix Propagation Using an Approximate Driving Noise Model", dated 2 January 1973.

11) 73-SD-21 dated 9 February 1973.

a) 23A STS Memo No. 5-73, "ILS Error Model for Shuttle Approach and Landing Navigation Studies," dated 18 January 1973.

12) 73-SD-23 dated 13 February 1973.

a) 23A STS Memo No. 60-72, "Shuttle UV Horizon Sensing Orbit Navigation Performance Part II: Horizon Sighting Direction and Frequency Requirements," 15 December 1972.

U K :s

TASK NO. SSTD-GN&C 4

TITLE: Component Requirements Definition

OBJECTIVE: Perform Studies and Analysis to determine functional and performance requirements, alignment tolerances, and acceptable error budgets for all components of the GN&C system for all flight phases.

STATUS: Complete

SD ENGINEERING CONTACT: M. Campbell

DL ENGINEERING CONTACT: N Sears

START/FINISH DATES: 8 December 1972 to 1 March 1973

REPORTS AND MEMOS:

SSTD GN&C-3,-4&-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 GN&C-3,-4&-7 are listed under SSTD GN&C-3 only.

U K :s

TASK NO. SSTD-GN&C 5

TITLE: Review of Mission Requirements

OBJECTIVE: Review, critique and update mission requirements documentation supplied by SD to determine adequacy, accuracy and depth of coverage. Identify the critical missions which strongly influence design.

STATUS: Complete

SD ENGINEERING CONTACT: M. Campbell

DI ENGINEERING CONTACT: N. Sears

START/FINISH DATES: 10 November 1972 to 1 February 1973

REPORTS AND MEMOS:

1) 72-SD-13 dated 27 December 1972.

a) DG Memo No. 1812, "Review and Comments

on NAR 'Design Reference Mission Data Book', dated 22 December 1972.

b) DG Memo No. 1813, "Review of 'Preliminary Mission Planning Guidelines and Constraints', dated 26 December 1972.

2) 73-SD-15 dated 9 February 1973.

a) Transmittal of January 1973 Presentation Material for SSTD GN&C-5.

U K :s

TASK NO. SSTD-GN&C 6

TITLE: GN&C Development Plan

OBJECTIVE: Prepare a preliminary GN&C Development Plan in several levels of detail showing the GN&C development efforts required to Critical Design Review including start and completion date and brief task descriptions. Exclude those aspects which are pure control functions.

STATUS: Complete

SD ENGINEERING CONTACT: M. Campbell

DL ENGINEERING CONTACT: N. Sears

START/FINISH DATES: 10 November 1972 to 23 February 1973

REPORTS AND MEMOS:

1) 73-SD-7 dated 15 January 1973.

a) MIT/DL Memo, "List of Documents Used On Apollo for the Definition and Procurement of the G&N System", dated 10 January 1973.

2) 73-SD-16 dated 2 February 1973.

a) Transmittal of January 1973 Review Presentation Material for SSTD GN&C-6.

3) 73-SD-30 dated 16 February 1973.

a) Transmittal of Rough Draft of MIT/DL Prepared "GN&C Development Plan".

4) 73-SD-35 dated 23 February 1973.

a) Transmittal of Final Report on "GN&C Development Plan".

U K :s

TASK NO. SSTD-GN&C 7

TITLE:	GN&C Analysis Math Models & Error Budgets
OBJECTIVE:	Derive and document math models and error budgets for all major GN&C assemblies (IMU, Optics, etc) and environment models (wind, gravity, etc) to level of details required for use in performance analysis studies. Both deterministic and stochastic models shall be derived and will include characteristics of ground based equipment, i.e., TACANS, ILS, etc.
STATUS:	Complete
SD ENGINEERING CONTACT:	M. Campbell
DL ENGINEERING CONTACT:	N. Sears
START/FINISH DATES:	17 November 1972 to 15 February 1973
REPORTS AND	

MEMOS:

SSTD GN&C-3,-4&-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 GN&C-3,-4&-7 are listed under SSTD GN&C-3 only.

U K :s

TASK NO. SSTD-GN&C 8

TITLE:	Review of GN&C Software Requirements
OBJECTIVE:	Review and critique preliminary baseline software requirements to determine adequacy of coverage and level of detail. Review each identifiable module considered with respect to correctness and depth of definition, amount of structuring, and partitioning of GN&C modules functions.
STATUS:	Completed
SD ENGINEERING CONTACT:	M. Campbell
DL ENGINEERING CONTACT:	J. Kernan
START/FINISH DATES:	17 November 1972 to 1 February 1973
REPORTS AND MEMOS:	
1)	72-SD-12 dated 21 December 1972.

a) MIT/DL Report C-3875, "Review of Space Shuttle GN&C Software Design Requirements Document as a Flight Programming Specification", dated 21 December 1972.

2) 73-SD-17 dated 2 February 1973.

a) Transmittal of January 1973 Review Material Prepared for SSTD GN&C-8.

U K :s

TASK NO. SSTD-GN&C 9

TITLE: Entry Interface Dispersions and Navigation Uncertainties

OBJECTIVE:

1. Determine position and velocity deviation and navigation uncertainties at entry interface for Mission 3 with or without star-horizon navigation updates and for a 7 day 100 mi orbit using star-horizon navigation.

2. Determine IMU alignment procedure and state vector update procedure etc.

STATUS: Completed

SD ENGINEERING CONTACT: M. Campbell/M. Madden

DL ENGINEERING CONTACT: N. Sears/E. Muller

START/FINISH DATES: 26 December 1972 to 14 February 1973

REPORTS AND
MEMOS:

1) 72-SD-17 dated 29 December 1972.
   a) Transmittal of Memo to M. Madden from G. Muller, dated 28 December 1973.

2) 72-SD-18 dated 29 December 1972.
   a) 23A STS Memo No. 67-72, "Covariance of Deviation in Flight-Path Angle at Entry Interface", dated 22 December 1972.

3) 73-SD-1 dated 5 January 1973.
   a) Transmittal of Memo to M. Madden from G. Muller, dated 4 December 1972.

4) 73-SD-22 dated 14 February 1973.
   a) 23A STS Memo No. 1-73, "Short Term Performance of Shuttle IR Horizon Sensing Orbit Navigation System", dated 4 January 1973.
   b) 23A STS Memo No. 2-73, "Entry Interface Navigation Uncertainties", 4 January 1973.

U K :s

TASK NO. SSTD-GN&C 10

TITLE:	Use of Transponder or Ground Tracking for IMU Calibration and Alignment During Boost and Insertion.
OBJECTIVE:	Determine orbit insertion accuracies achievable using transponders or ground tracking for state updates and IMU calibration and alignment during boost and insertion. Both gimballed platforms and strapdown inertial reference units shall be considered.
STATUS:	Complete
SD ENGINEERING CONTACT:	M. Campbell/M. Madden
DL ENGINEERING CONTACT:	N. Sears
START/FINISH DATES:	1 February 1973 to 2 May 1973.
REPORTS AND	

MEMOS:

1) 73-SD-19 dated 9 February 1973.
   a) Transmittal of January 1973 Review Presentation Material for SSTD GN&C-10.

2) 73-SD-55 dated 29 March 1973.
   a) 23A STS Memo No. 21-73, "Refraction Error Model for One-Way Doppler", 8 March 1973.
   b) 23A STS Memo No. 22-73, "Measurement-Sensitivity Vector for One-Way Doppler during Powered-Boost Phase", 13 March 1973.

3) 73-SD-57 dated 4 April 1973.
   a) 23A STS Memo No. 27-73, "Including Refraction and Transmitter Location Bias Errors in One-Way Doppler Statistical Analyses", 27 March 1973.

4) 73-SD-75 dated 2 May 1973.
   a) 23A STS Memo No. 38-73, "Boost Phase Navigation Using One-Way Doppler and IMU Measurements", 5 May 1973.

5) 73-SD-86 dated 17 May 1973.
   a) 23A STS Memo No. 41-73, "Shuttle

Boost-Phase Navigation", 11 May 1973.

6) 73-SD-102 8 June 1973.

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

U K :S

TASK NO. SSTD-GN&C 11

TITLE:	Approach Guidance Energy Management Study
OBJECTIVE:	Provide Consultation and analysis support of McDonnell-Douglas Corporation (St. Louis) in their simulation studies for SD of Shuttle orbiter energy management techniques during transition and approach.
STATUS:	Completed
SD ENGINEERING CONTACT:	H. Ehlers
DL ENGINEERING CONTACT:	A. Elias
START/FINISH DATES:	5 January 1973 to 20 March 1974.
REPORTS AND MEMOS:	1) 73-SD-8 dated 15 January 1973.

a) 23A STS Memo #4-73, "Approach Guidance can be used for Boost Aborts", dated 8 January 1973.

b) Space Shuttle GN&C Equation Document #23, "Energy Dissipation Rate Guidance for Approach Phase", January 1973.

2) 73-SD-18 dated 9 February 1973.

a) Transmittal of January 1973 Review Presentation Material for SSTD GN&C-11.

3) 73-SD-43 dated 8 March 1973.

a) 23A STS Memo No. 11-73, "Approach Phase Guidance-New Results with Winds", dated 6 February 1973.

4) 73-SD-62 dated 18 April 1973.

a) 23A STS Memo No. 29-73, "VORTAC Reference Guidance System for Terminal Area Energy Management (TAEM)", 2 April 1973.

5) 73-SD-79 dated 7 May 1973.

a) 23A STS Memo No. 36-73, "Energy Rate Switching Criterium for Vortac Reference Guidance System," 26 April 1973.

6) 73-SD-116 dated 27 July 1973.

a) 23A STS Memo No. 61-73, "Targeting Criteria for TAEM Guidance", 16 July 1973.

b) 23A STS Memo No. 62-73, "Wind Compensation Problems in TAEM Guidance", 17 July 1973.

7) 74-SD-3 dated 5 February 1974.

a) Shuttle Memo No. 10E-74-1, "Interface Between Alpha -- Transition and TAEM Phases", 18 January 1974.

8) 74-SD-18 dated 5 April 1974.

a) CSDL Report C-4082, "Space Shuttle G&N Equation -- Document No. 27, Terminal Area Energy Management (TAEM) -- Guidance," March 1974.

U K :s

TASK NO. SSTD-GN&C 12

TITLE: Backup GN&C Computer Minimal Sizing

OBJECTIVE: Considering more than half of the storage space in the onboard backup GN&C computer is allocated for system functions (housekeeping), conduct a study to determine maximum in depth reduction of these functions. In particular, investigate minimal display, control and moding and FDI (replace with simple voting mechanism) functions.

STATUS: Completed

SD ENGINEERING CONTACT: M. Chadwick

DL ENGINEERING CONTACT: J. Kernan

START/FINISH DATES: 29 January 1973 to 16 February 1973

REPORTS AND MEMOS:

1) 73-SD-29 dated 16 February 1973.

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

U K :s

TASK NO. SSTD-GN&C 13

TITLE: Orbit Navigation Using Various Sensors

OBJECTIVE: Orbit navigation studies shall be performed for missions to be specified including Missions 1,2 3A & 3B.

STATUS: Completed

SD ENGINEERING CONTACT: M. Madden

DL ENGINEERING CONTACT: E. Muller

START/FINISH DATES: 1 February 1973 to 1 October 1973 (Redirected to SSTD GN&C-24 and 29.)

REPORTS AND MEMOS:

1) 73-SD-42 dated 6 March 1973.

a) MIT/DL Memo from E. Muller to M. Madden," GN&C TD No. 13 Orbit Navigation

Study", 2 March 1973.

b) 23A STS Memo No. 61-71, "Status Report on Shuttle Ground Beacon Orbit Navigational Analysis," 8 December 1971.

2) 73-SD-50 dated 16 March 1973.

a) 23A STS Memo No. 20-73, "Orbital Navigation Using Various Sensors", dated 8 March 1973.

3) 73-SD-53 dated 21 March 1973.

a) 23A STS Memo No. 16-73, "Navigation Sensor Study for a Short Mission (3A)", dated 2 March 1973.

4) 73-SD-87 dated 17 May 1973.

a) 23A STS Memo No. 39-73, "Horizon Sensor Error Study Using Correlated Noise with a Six Component Sensor", 8 May 1973.

5) 73-SD-103 dated 13 June 1973.

a) 23A STS Memo No. 51-73, "Navigation With Altitude Measurements Only Using a Horizon Sensor and a Radar Altimeter, 31 May 1973.

U K :s

TASK NO. SSTD-GN&C 14

TITLE: GN&C Performance Analysis for 150K Orbiter Design

OBJECTIVE: An integrated GN&C analysis of several short missions shall be performed to include missions 3A, 3B & several once-around missions.

STATUS: Completed

SD ENGINEERING CONTACT: M. Madden

DL ENGINNEERING CONTACT: G. Levine

START/FINISH DATES: 19 February 1973 to 2 August 1974.

REPORTS AND MEMOS:

1) 73-SD-27 dated 15 February 1973.
   a) Acknowledgement of the Receipt of Data from NR for SSTD GN&C-14.

2) 73-SD-34 dated 23 February 1973.

a) 23A STS Memo No. 13-73, "Launch-Pad Alignment of IMU by Gyro-Compassing --Effect of Gyro Errors on Alignment Accuracy", dated 12 February 1973.

3) 73-SD-39 dated 28 February 1973.

a) 23A STS Memo No. 13-73 (Rev.1), "Launch-Pad Alignment of IMU by Gyro-Compassing--Effect of Gyro Errors on Alignment Accuracy", 12 February 1973.

b) 23A STS Memo No. 17-73, "Post-Blackout Entry and Approach Phase Footprints for the NR 150K Orbiter Vehicle," dated 26 February 1973.

4) 73-SD-44 dated 7 March 1973.

a) 23S Memo No. 72-67, (Rev3), "Parameters for GN&C Subsystem Error Models",

5) 73-SD-48 dated 15 March 1973.

a) DG Memo No. 1817, "Star Availability for Space Shuttle IMU Alignment with Three Star Trackers", dated 3 March 1973.

6) 73-SD-48A dated 17 April 1973.

a) 23S Memo No. 78-73, "Kalman Filtering of

Star Measurements for Space Shuttle IMU Alignment", dated 18 April 1973.

7) 73-SD-49 dated 16 March 1973.

a) 23N STS Memo No. 11, "Black-out of Radio Transmission During Re-entry of STS", dated 10 September 1970.

8) 73-SD-56 dated 30 March 1973.

a) 23A STS Memo No. 19-73, "Approach and Landing Navigation Performance Using Updated VOR/DME AND ILS ERROR MODELS," 8 March 1973.

9) 73-SD-59 dated 9 April 1793.

a) Transmittal of Space Shuttle GN&C Equation Documents pertinent to SSTD GN&C-14, (16 documents).

10) 73-SD-63 dated 18 March 1973.

a) 23A STS Memo No. 10-71, "Drag Measurement as a Possible Means for Reducing Altitude Estimation Errors During SSV Entry," 25 January 1971.

b) 23A STS Memo No. 26-71 "Stabilization of the Altitude Component of the Orbiters

State-Vector Estimate During Entry", 9 April 1971.

c) 23A STS Memo No. 10-73, "Entry Approach and Landing Navigation Studies", 2 Frbruary 1973.

11) 73-SD-91 dated 23 May 1973.

a) 23A STS Memo No. 42-73 "Guidance and Navigation System Performance Study for Mission 3A Aborts", 11 May 1973.

b) 23A STS Memo No 45-73, "Sensitivity of State Estimimation Errors to IMU Initial Alignment Errors--Estimation and IMU Errors", 16 May 1973.

c) 23A Memo No. 46-73, "Calculation of IMU Error Sensitivities from Correlations Between State-Estimation and IMU Errors", 16 May 1973.

12) 73-SD-95 dated 30 May 1973.

a) 23A STS Memo No. 48-73, "Shuttle Entry and Transition Phase Guidance (Viewgraphs)", 21 May 1973.

13) 73-SD-97 dated 1 June 1973.

a) 23A STS Memo No. 49-73, "Recent Approach and Landing Navigation Studies", 29 May

1973.

14) 73-SD-99 dated 7 June 1973.

a) 23S Memo No. 72-67, Rev. 4, "Parameters for GN&C Subsystem Error Models", 6 June 1973.

15) 73-SD-108 dated 2 July 1973.

a) 23A STS Memo No. 54-73, "Sensitivity of Required TPS Weight to Variations in Vehicle State at Entry Interface, -Mission 3A Abort", 18 June 1973.

b) 23A STS Memo No. 56-73, "Additional IMU Performance Studies for Mission 3A Abort", 18 June 1973.

16) 73-SD-14 dated 20 July 1973.

a) 23A STS Memo No. 63-73, "Navigation-System Performance for 3A-Abort Mission-Latter Part of Entry to Touchdown", 12 July 1973.

17) 73-SD-115 dated 23 July 1973.

a) 23A STS Memo No. 55-73, "Thrust Direction Turning Rate for Large Central Angle Shuttle Deorbit Maneuvers", 19 June 1973.

b) 23A STS Memo No. 57-73, "Effect of

Performing Shuttle Deorbit at T/W Different from Targeted Value", 20 June 1973.

c) 23A STS Memo No. 58-73, "The Space Shuttle Project Should Use Ephemeris Time Rate and Ephemeris Time (of day)," 3 June 1973.

18) 73-SD-122 dated 1 August 1973.

a) 23A STS Memo No. 66-73, "Mission #3A-Abort Performance Data with One-Way Doppler Measurements During Boost", 1 August 1973. SSTD GN&C-14 6/73.

19) 73-SD-143 dated 13 September 1973.

a) 10E STS Memo No. 71-73, "The Leap Second", 11 September 1973.

20) 73-SD-147 dated 21 September 1973.

a) 10E STS Memo No. 74-73, "Generation of Maximum Range RTLS Glide Trajectory 17 September 1973.

21) 73-SD-150 dated 10 October 1973.

a) 10E STS Memo No. 75-73, "Verification of the Unified Powered Flight Guidance Program", 27 September 1973.

b) CSDL Memo dated 17 September from J.P.

Higgins, "Errata for Space Hsuttle GN&C Equation Document No. 24, Unified Power Flight Guidance, June 1973".

22) 73-SD-159 dated 9 November 1973.

a) 10E STS Memo No. 80-73, "Maximum Range RTLS Glide Trajectories from 205,000 Ft"., 2 November 1973.

23) 73-SD-173 dated 12 December 1973.

a) 10E STS Memo No. 85-73, "Astronaut Modification of the Rendezvous Sequence," 5 December 1973.

U K :s

TASK No. SSTD-GN&C 15

TITLE: GN&C Vehicle Software RFD Definition

OBJECTIVE: Conduct a study to determine a) the format and arrangement of each RFD to facilitate integration of the group, b) the potential problems inherent in the integration process, and c) preferred methodology for integration.

STATUS: Complete

SD ENGINEERING CONTACT: D. Engels

DL ENGINEERING CONTACT: N. Sears

START/FINISH DATES: 1 February 1973 to 1 May 1973

REPORTS AND MEMOS:

1) 73-SD-73 dated 26 February 1973.

a) MIT/DL Report No. C-3899, "Design of the

GN&C Flight Software Specification", 26 February 1973.

2) 73-SD-74 dated 1 May 1973.

a) Shuttle Management Memo No. 25, "Examples of Shuttle GN&C Software Specifications", 30 April 1973.

U K :s

TASK NO. SSTD-GN&C 16

TITLE: GN&C Performance Requirements Report

OBJECTIVE:

1. Determine the functional and performance requirements of the G&N subsystem and its major components (e.g. IMU).

2. Prepare and deliver a report describing these requirements, the error models used, error sensitivities and error budgets for G&N components.

3. This SSTD is the preparation of the final report for SSTD GN&C-14.

STATUS: Completed

SD ENGINEERING CONTACT: D. Engels

DL ENGINEERING CONTACT: G. Levine

START/FINISH DATES: 1 March 1973 to 2 August 1974.

REPORTS AND MEMOS:

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

U K :s

TASK NO. SSTD-GN&C 17

TITLE: GN&C Operating System Software Definition

OBJECTIVE:

1) Define and describe the contents of the following functions in the GN&C computer: System utility, subroutine library, subsystem control and moding, subsystem fault detection and isolation, subsystem calibration and testing, common pool and temporary storage, entry routines.

STATUS: Complete

SD ENGINEERING CONTACT: M. Chadwick

DL ENGINEERING CONTACT: J. Kernan

START/FINISH DATES: 15 February 1973 to 18 May 1973.

REPORTS AND

MEMOS:

1) 73-SD-29 dated 16 February 1973.

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

2) 73-SD-90 dated 18 May 1973.

   a) MIT/DL Shuttle Software Memo No. 52, "Description and Size of GN&C System Functions", 15 May 1973.

U K :s

TASK NO. SSTD-GN&C 18

TITLE: Summary of MIT/DL Analysis Programs

OBJECTIVE: Prepare and deliver to SD a summary list of the computer programs in use or available for use at MIT/DL of value for current and future analysis of Space Shuttle GN&C and provide a brief description of each.

STATUS: Complete

SD ENGINEERING CONTACT: M. Chadwick

DL ENGINEERING CONTACT: G. Levine

START/FINISH DATES: 1 March 1973 to 15 June 1973

REPORTS AND MEMOS:

1) 73-SD-47 dated 14 March 1973.

a) 23A SGA Memo No. 4-72, "General Least

Square, Least Power, and Chebyshev 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 Matrix Extrapolation."

c) Space Shuttle GN&C Equation Document No. 10, Rev. 1, "Conic Required Velocity Determination".

d) MIT/DL Memo "Users Guide to SMRSS7. LAMBERT", dated 18 November 1971.

e) 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 Average-G (Heun) Method", dated 16 August 1973.

g) 23A STS Memo No. 18-73, "WMR.

ASTRODYN-A Comprehensive MAC Subroutine for Astrodynamic Calculation", dated 1 March 1973.

h) MAC Program Cards and Listing for LEASTSQR, LEASTPWR, CHEBSHEV, TEST LEASTSQ and TEST CHEBSHEV.

i) MAC Program Cards and Listing for RVWXHEUN, RVWXTRAP, and KEPLER.

j) MAC Program Cards and Listing for LAMBERT, MRSHRINV, KPLREQN AND SEARCH.

k) MAC Program Listing for WMR. ASTRODYN.

2) 73-SD-58 dated 5 April 1973.

a) 23A STS Memo No. 30-73, "Summary of MIT/DL Astrodynamic and Mathematical Analysis Programs" 3 April 1973.

3) 73-SD-64 dated 19 April 1973.

a) MIT/DL Memo to M.C Chadwick from E.S. Muller, "MIT/DL Rendezvous and Orbit Navigation Analysis Computer Programs", 16 April 1973.

b) MIT/DL Memo to M.C. Chadwick from J.

Higgins, "Shuttle Boost Simulator," 19 April 1973.

4) 73-SD-78 dated 3 May 1973.

a) MIT/DL Memo to M. Madden from E. Muller, "Transmittal of Program Decks and Listings for Error Vector Generation Routine", dated 3 May 1973.

5) 73-SD-84 dated 15 May 1973.

a) 23A SGA Memo No. 2-73, "Adding Process Noise to a Square Rout Covariance Matrix via "REP.HOUSEBIG", 14 May 1973

b) Kaminski, et al., IEEE Transactions on Control, Vol. AC-16 No. 6, December 1971, "Discrete Square Root Filtering, A Survey of Current Techniques".

c) 23A STS Memo No. 49, "MAC Programs to: Trianqularize a Matrix by Householder Transformations".

d) Program Listing and Cards for the REP.HOUSEBIG Program.

6) 73-SD-105 dated 15 June 1973.

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

U K :s

TASK NO. SSTD-GN&C 19

TITLE:	Passive Rendezvous Sensor Requirements Definition
OBJECTIVE:	Define and describe functional and performance requirements for a Shuttle passive rendezvous sensor.
STATUS:	Complete
SD ENGINEERING CONTACT:	R. Varian/A. Bologna
DL ENGINEERING CONTACT:	G. Levine/E. Muller
START/FINISH DATES:	1 February 1973 to 20 February 1973.
REPORTS AND MEMOS:	

1) 73-SD-32 dated 20 February 1973.
   a) MIT/DL Memo, "Passive Rendezvous Study Results (Task 19)" dated 16 February 1973.

2) 73-SD-38 dated 27 February 1973.

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 Memo, "Updated Radar Search Angle Requirements for Mission 3B", dated 16 March 1973.

U K :s

TASK NO. SSTD-GN&C 20

TITLE: Simplified Shuttle Abort G&N Study

OBJECTIVE: TBD

STATUS: Withdrawn

SD ENGINEERING
CONTACT: D. Engels

DL ENGINEERING
CONTACT: N. Sears

START/FINISH
DATES: TBD

REPORTS AND
MEMOS:

U K :S

TASK NO. SSTD-GN&C 21

TITLE: IMU Derived Attitude and Attitude Rate

OBJECTIVE: 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.

STATUS: Completed

SD ENGINEERING
CONTACT: J. Jansen

DL ENGINEERING
CONTACT: G. Edmonds/R. Schlundt

START/FINISH
DATES: 9 April 1973 to 23 April 1973.

REPORTS AND
MEMOS:

1) 73-SD-80 dated 8 May 1973.
   a) SSV Memo No. 73-23C-7, "State Estimator for the Shuttle On-Orbit Autopilot," 19 April 1973.
   b) SSV Memo No. 73-23C-8, "On-Orbit Angular Velocity Estimation Accuracies Using IMU Gimbal Angle Measurements", 1 May 1973.

U K :s

TASK NO. SSTD-GN&C 22

TITLE: Passive Rendezvous Sensor Requirements Definition (Extension)

OBJECTIVE:

1) Define required measured parameters and required accuracy of these measurements (random and bias) for Mission 3B for two basic operational modes:
   a) Automatic -- assumes filtering of navigation measurements (e.g. using the Unified Navigation Filter) and automatic execution of braking and LOS corrections.
   b) Manual -- assumes display of raw measurement data from which astronaut can make appropriate braking and LOS corrections.

   Measurements considered will be: range, range rate, LOS angles, angle rates.
2) Define sensor requirements (accuracies, maximum acquisition range) for general passive rendezvous mission (other than 3B).
   a) Consider using star tracker to track

target using reflected sunlight at long ranges with skin tracking radar at short ranges.

b) Examine different possible rendezvous trajectories.

3) Determine sources and magnitudes of max-min range limits for conduct of rendezvous mission 3B.

(this TD is an extension of TD #GN&C-19)

STATUS: Completed

SD ENGINEERING CONTACT: M. Campbell

DL ENGINEERING CONTACT: N. Sears

START/FINISH DATES: 14 March 1973 to 1 October 1973.

REPORTS AND MEMOS:

1) 73-SD-51 dated 19 March 1973.

a) MIT/DL Memo, "Updated Radar Search Angle Requirements for Mission 3B (Task 19),"

dated 16 March 1973.

2) 73-SD-67 dated 24 April 1973.

   a) MIT/DL Memo to A. Bologna, "TD No. 22 (Rendezvous Sensor Study)", from E. Muller, dated 24 April 1973.

3) 73-SD-70 dated 24 April 1973.

   a) 23A STS Memo No. 33-73, "Orbiter Rendezvous and Terminal Phase Analysis (Viewgraphs)", 19 April 1973.

4) 73-SD-72 dated 26 April 1973.

   a) MIT/DL Memo to A. Bologna, "TD No. 22 (Rendezvous Sensor Study)", from E. Muller, dated 26 April 1973.

5) 73-SD-88 dated 17 May 1973.

   a) 23A STS Memo No. 52-71, "The Secondary Constraints Employed in the Orbiter Rendezvous Targeting Program", 15 October 1971.

   b) 23A STS Memo No. 55-71, "A Skylab Rendezvous Trajectory Computed with the Orbiter Targeting Program", 12 October 1971.

   c) 23A STS Memo No. 8-72, "The Iterative

Algorithm Used in the Elevation Angle Search in the Rendezvous Targeting Program", 11 February 1972.

d) 23A STS Memo No. 9-72, "Users Guide to the Shuttle Rendezvous Targeting Program", 12 March 1972.

e) 23A STS Memo No. 15-72, "The Design of the Shuttle Rendezvous Targeting Program", 8 March 1972.

f) 23A STS Memo No. 35-73, "The Computation of the Mission 2 Rendezvous Profile Using the Shuttle Rendezvous Targeting Program", 2 May 1973.

g) MIT/DL Report E-2713, "Rendezvous Targeting for Space Missions", September 1972.

6) 73-SD-89 dated 17 May 1973.

a) 23A STS Memo No. 44-73, "Rendezvous Sensor Requirements for Long Range Rendezvous Missions and Search Angle Requirements for Mission 3B", 15 May 1973.

7) 73-SD-92, dated 23 May 1973.

a) MIT/DL Memo to R. Reid from E. Muller, "TD Nos. 22 and 23", 22 May 1973.

D K :s

TASK NO. SSTD-GN&C 23

TITLE: Effect of Thermal Conditioning Operation on Shuttle Navigation System Performance

OBJECTIVE: 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 technigue (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

every 20 min to steadystate or 12 hours whichever occur first.

d. Case b. and c. augmented with altitude data.

e. Case b. and c. with horizon sensors replaced with one-way doppler for which measurement frequency and durations are TBD.

Performance will be evaluated by comparing on-orbit covariance matrices after 1, 1.5, 2, 3, and 5.5 hours of navigation and by comparing entry interface covariance matrices and flight path angle uncertainites after navigation periods of 1.5, 5.5 hours, and after steadystate or 12 hours.

Assumptions and Initial Conditions

1. Eight hours of on-orbit operation without navigation.
2. IMU alignment allowed just prior to the initiation of navigation.
3. Initial SV and alignment accuracies consistent with 1. and 2.
4. BBQ mode performed with body X axis in the orbit plane and perpendicular to the sun line (sun synchronous orbit). Roll motion is maintained about this axis at 0.5 deg/sec (0.3 deg/sec for case c) while the X axis is

maintained locally level by a normal to the orbit plane rotation at orbit rate.

5. The orbital parameters for the circular orbit are

   i = 104 deg

   h = 100 nm

6. The deorbit maneuver requirements assume baseline deorbit (single OMS retro) for 150K lb. Orbiter and TBD lb. payload and propellant load.

7. Coverage for one-way doppler will be such that the frequency of tracking periods will be TBD and the duration of tracking will be TBD for each period. Tracking stations will be TBD only. Assume max utilization: i.e., nav. sequence begins at a lat-long such that the greatest number of ground stations can be used during the nav. period.

STATUS: Completed

SD ENGINEERING CONTACT: R. Reid

DL ENGINEERING CONTACT: E. Muller

START/FINISH DATES: 9 April 1973 to 22 April 1973

REPORTS AND MEMOS:

1) 73-SD-65 dated 23 April 1973.
   a) MIT/DL Memo to M. Madden, "TD No. 23", from E. Muller, dated 20 April 1973.

2) 73-SD-73 dated 30 April 1973..
   a) MIT/DL Memo to M. Madden, "TD No. 23 (Case e - One-Way Doppler)", from E. Muller 27 April 1973.

3) 73-SD-76 dated 2 May 1973.
   a) MIT/DL Memo to R. Reid, "TD No. 23", from E. Muller dated 30 April 1973.

4) 73-SD-92 dated 23 May 1973.
   a) MIT/DL Memo to R. Reid, "TD Nos. 22 and 23", from E. Muller, 22 May 1973.

5) 73-SD-93 dated 22 May 1973.
   a) 23A STS Memo No. 43-73, "Effect of Barbeque Mode and Doppler Antenna Constraints on Shuttle Orbit Navigation Performance", 15 May 1973.

U K :s

TASK NO. SSTD-GN&C 24

TITLE: Support of Navigation Evaluation

OBJECTIVE: Design and run a number of test cases in order to support the evaluation and comparison of the TRW and Draper Laboratory navigation filters. Also provide technical consulation as required to support this effort.

STATUS: Terminated

SD ENGINEERING CONTACT: D. Engels

DL ENGINEERING CONTACT: G. Levine

START/FINISH DATES: 20 April 1973 to 2 August 1974.

REPORTS AND MEMOS:

1) 73-SD-68 dated 24 April 1973.
   a) Notification to the SD of transmittal of

the following documents to Intermetrics.

b) MSC Internal Note No. 71-FM-343, "State Propagation in the Mulitphase Filter", dated August 30, 1971.

c) MIT/DL E-2637, "Results of Space Shuttle Computer Floating - Point Precision Study", January 1972.

d) Space Shuttle GN&C Equation Document No. 5, Rev 2, "Rapid Real-Time State and Filter Weighting Matrix Advancement during Specific Force Sensing", November 1972.

e) Space Shuttle GN&C Equation Document No. 4 Rev. 3, "Precision State and Filter Weighting Matrix Extrapolation", October 1972.

f) Space Shuttle GN&C Equation Document No. 3 Rev. 2, "Conic State Extrapolation", October 1972.

g) Space Shuttle GN&C Equation Document No. 12, Rev. 2, "Entry Approach and Landing Navigation".

h) Space Shuttle GN&C Equation Document No. 16, "Station-Keeping Navigation", March 1972.

i) Space Shuttle GN&C Equation Document No. 21, "Shuttle Unified Navigation Filter", November 1972.

j) "Ground Beacon Orbit Navigation Analysis",

E.S. Muller Jr. MIT/CSDL.

k) 23A STS Memo No. 11-72, "Entry and Terminal Phase Navigation for SSV Orbiter Using MLS or AILS, and VOR/DME", 16 February 1973.

l) 23A STS Memo No. 23-72, "Entry, Approach and Landing Navigation Routine", 28 March 1972.

m) 23A STS Memo No. 41-72, "Navigation Errors on Various Shuttle Approach Trajectories", 14 June 1972.

n) 23A STS Memo No. 44-72, June 1972. "Scheme of Inhibiting Crosstrack Updates on Near Direct Overhead Beacon Passes (Shuttle Ground Beacon Orbit Navigation System)", 1 August 1972.

o) 23A STS Memo No. 53, "Comments on Navigation Errors Using Various Navigation Aids During a Space Shuttle Reentry and Landing", 17 October 1972.

p) 23A STS Memo No. 68-72, W-Matrix Propagation Using an Approximate Driving Noise Model, 2 January 1973.

q) 23A STS Memo No. 5-73, ILS Error Model for Shuttle Approach and Landing Navigation Studies", 18 January 1973.

r) 23A STS Memo No. 9-73, "Shuttle Navigation Filter Presentation at MSC (MPAD) Meeting, 18 January 1973", 1 February 1973.

s) 23A STS Memo No. 10-73, "Entry Approach and Landing Navigation Studies", 2 February 1973.

t) 23A STS Memo No. 12-73, "Recommended Filter State Dimension in Unified Navigation Filter for Each Shuttle Mission Phase", 6 February 1973.

u) 23A STS Memo No. 19-73, "Approach and Landing Navigation Performance Using Updated VOR/DME and ILS Error Models", 8 March 1973.

2) 73-SD-69 dated 23 April 1973.

a) Transmittal letter to Intermetrics of documents listed above for 73-SD-68.

3) 73-SD-82 dated 11 May 1973.

a) Transmittal of the following memo to Intermetrics: Space Guidance Analysis Memo No. 4-70, "Explicit Analytic Expressions for the Terms in a Spherical Harmonic Expansion of the Gravitational Acceleration Due to Oblateness", 26 May 1973.

4) 73-SD-123 dated 3 August 1973.

a) CSDL Memo to D. Engels from E. Muller/P. Kachmar, "Test Case Results for TD No. 24", 31 July 1973.

5) 73-SD-127 dated 10 August 1973.

a) 23A STS Memo No. 68-73, "TD No. 24 with Enclosure Test Case Results for TD No. 24".

6) 73-SD-156 dated 30 October 1973.

a) 10E STS Memo No. 79-73, "Measurement Second Partials--Shuttle Entry and Landing Mission Phases", 19 October 1973.

7) 73-SD-164 dated 7 December 1973.

a) 10E STS Memo No. 84-73, "Navigation Filter Evaluation for Orbit Navigation Phase-Preliminary Results", 26 November 1973.

8) 73-SD-166 dated 10 December 1973.

a) 10E STS Memo No. 83-73, "Navigation Filter Evaluation for Entry and Landing Phase-Preliminary Results", 19 November 1973.

9) 73-SD-4 dated 5 February 1974.

a) Shuttle Memo No. 10E-74-2, "Entry and Landing Navigation Filter Studies", 21

January 1974.

b) Shuttle Memo No. 10E-74-3, "Measurement Residuals on Selected Entry and Landing Simulation Runs," 29 January 1974.

10) 74-SD-6 dated 15 February 1974.

a) Shuttle Memo No. 10E-74-4, "Comparison of Entry-Navigation-Filter UnderWeighting Schemes with Large Initial Condition Errors", 31 January 1974.

b) Shuttle Memo No. 10E-74-5, "Navigation Errors During Entry-No TACAN, Baro or OWD Updates", 5 February 1974.

c) Shuttle Memo No. 10E-74-10, "Shuttle Navigation Filter Evaluation (Orbit Navigation)," 6 February 1974.

11) 74-SD-7 dated 4 March 1974.

a) Shuttle Memo No. 10E-74-11, "Small State Size and Low Update Rates for the Entry-and-Landing Navigation Filter", 7 February 1974.

12) 74-SD-9 dated 12 March 1974.

a) Shuttle Memo No. 10E-74-7, "Shuttle Navigation Filter Evaluation Mission Phase: Rendezvous (No. 2 of 4)", 12 February 1974.

13) 74-SD-11 dated 14 March 1974.

a) Shuttle Memo No. 10E-74-6, "Shuttle Navigation Filter Evaluation Mission Phase: Rendezvous (No. 1 of 4)," 6 February 1974.

14) 74-SD-15 dated 28 March 1974.

a) Shuttle Memo No. 10E-74-9, "Shuttle Navigation Filter Evaluation Mission Phase: Rendezvous (No. 4 of 4)," 20 February 1974.

15) 74-SD-16 dated 29 March 1974.

a) Shuttle Memo No. 10E-74-8, "Shuttle Navigation Filter Evaluation Mission Phase: Rendezvous (No. 3 of 4)," 20 February 1974.

16) 74-SD-25 dated 12 June 1974.

a) Shuttle Memo No. 10E-74-27, "Navigation Filter Covariance Formulation Accuracy Studies-Viewgraphs Presented at JSC

189 Navigation Panel Mtg., 16 April 1974," 3

190 June 1974.

191

U K :s

TASK NO. SSTD-GN&C 25

TITLE:	GN&C Sensor Procurement Specification Support
OBJECTIVE:	Draper Laboratory will support the SD in the review of selected GN&C system sensor procurement specifications and make recommendations to the SD for modifications, corrections or additional information or requirements for such specifications.
STATUS:	Completed
SD ENGINEERING CONTACT:	D. Engels
DI ENGINEERING CONTACT:	G. Edmonds/R. McKern
START/FINISH DATES:	16 April 1973 to 15 December 1973.
REPORTS AND MEMOS:	1) 73-SD-66 dated 24 April 1973.

a) MIT/DL Memo to D. Engels and A. Zeitlin, "Quick Review of Preliminary IMU S.O.W. and IMU P.S.", dated 20 April 1973.

2) 73-SD-77 dated 3 May 1973.

a) 23S Memo No. 77-73 (Rev. 1) "Questions in Support of Shuttle IMU Performance", 12 April 1973.

3) 73-SD-94 dated 23 May 1973.

a) 23S Memo #88-73, "Review of Preliminary SD IMU Procurement Specification".

4) 73-SD-100 dated 7 June 1973.

a) DG Memo No. 1827A, "Proposed Baseline Shuttle Display Generator Hardware Instruction Set", 31 May 1973-Rev.1.

5) 73-SD-101 dated 8 June 1973.

a) 23A STS Memo No. 51-73, "Tolerances for Pitot-Static Dynamic Pressure Measuring System", 31 May 1973.

b) 23A STS Memo No. 52-73, BARO-Altimeter Requirements for Entry, Approach and Landing Navigation," 31 May 1973.

6) 73-SD-107 dated 29 June 1973.

a) DG Memo No. 1829, "Comparison of Display Lengths As a Function of Display Generator Instruction Set", 20 June 1973.

7) 73-SD-112 dated 16 July 1973.

a) 23S Memo No. 93-73, Trip Report-NAR, 4-5 June 1973", dated 19 June 1973.

8) 73-SD-116 dated 26 July 1973.

a) 23S Memo No. 110-73, "Response to NAR SD IL 392-JBP-73-013, Reliability Models for Monitored Redundant Systems", 24 July 1973.

9) 73-SD-117 dated 26 July 1973.

a) 23S Memo No. 111-73, "Trip Report-North American Rockwell Corp., July 16/20, 1973," 25 July 1973.

10) 73-SD-120 dated 31 July 1973.

a) 23S Memo No. 109-73, "The Shuttle and Gimbal Flip", 23 July 1973.

11) 73-SD-128 dated 13 August 1973.

a) 23S Memo No. 96-73, "Inflight Alignment

Errors-Star Tracker", 26 June 1973.

b) 23S Memo No. 100-73, "Misalignment of Star Tracker to NB", 6 July 1973.

c) 23S Memo No. 102-73, "Space Shuttle Star Tracker Errors", 6 July 1973.

d) 23S Memo No. 108-73, "Space Shuttle Star Tracker Locations", 19 July 1973.

e) 23S Memo No. 112-73, "SM Uncertainty Resulting from Sighting on Two Stars-A Comprehensive Perspective", 26 July 1973.

f) 10J Memo No. 1-73, "The Uncertainty in the NB to SM Transformations", 7 August 1973.

12) 73-SD-130 dated 14 August 1973.

a) Intralab Memo No. 10J-4-73, "Results of Recent Runs of Shuttle Crew Safety Probability Program", 14 August 1973.

13) 73-SD-133 dated 21 August 1973.

a) DG Memo No. 1827A, "Proposed Baseline Shuttle Display Generator Hardware Instruction Set", 31 May 1973 Rev. 1.

b) DG Memo No. 1829, Comparison of Display File Lengths as a Function of Display Generator Instruction Set" 20 June 1973.

c) DG Memo No. 1835, "Circuit and Packaging Technology for Shuttle Display Processor", 19 July 1973.

d) DG Memo No. 1836, PMS Annunication System", 30 July 1973.

14) 73-SD-135 dated 22 August 1973.

a). Intralab Memo No. 10J-2-73 Rev. 1, "Coverage Consideration", 20 August 1973.

15) 73-SD-138 dated 6 September 1973.

a) Intralab Memo No. 10J-9-73 "Improved IMU Model for Simulation of Kalman Filter in IMU Alignment," 23 August 1973.

b) Intralab Memo No. 10J-10-73, "Some Comments on Space Shuttle Inertial Reference Units Fine Alignment with the Optical Sensors", 29 August 1973.

16) 73-SD-154 dated 19 October 1973.

a) Intralab Memorandum No. 10J-14-73, "IMU Stable Member Misalignment Resulting from Multiple Error Sources", 1 October 1973.

b) Intralab Memorandum No. 10J-16-73, "Possible In-Flight Calibration and/or Test of Space Shuttle Star Trackers", 27

September 1973.

17) 73-SD-161 dated 14 November 1973.

a) Intralab Memo No. 10J-27-73, "Revision of Barometric Altitude Appendix of 23S Memo No. 72-67 Parameters for GN&C Subsystem Error Models", 7 November 1973.

U K :s

TASK NO. SSTD-GN&C 26

TITLE: Support of Intermetrics IMU FDI Test Plan Study

OBJECTIVE: Provide technical consultation to Intermetrics Inc. as required to support their effort to SD for the definition of a Test Plan for the Shuttle IMU fault detection and isolation (FDI) verification.

STATUS: Completed

SD ENGINEERING CONTACT: D. Engels

DL ENGINEERING CONTACT: R. McKern

START/FINISH DATES: 23 April 1973 to 15 November 1973.

REPORTS AND MEMOS:

1) 73-SD-141 dated 12 September 1973.

a) Avionics Memo No. 73-17, "Multiple IMU System Shuttle Baseline Testing at NASA/MSFC", 25 July 1973.

U K :s

TASK NO. SSTD-GN&C 27

TITLE:	Entry Guidance Evaluation Study
OBJECTIVE:	This effort will be a joint design evaluation effort between SD, JSC, and CSDL. The objective will be to evaluate various entry guidance concepts with respect to performance accuracy, GN&C computer requirements sensitivity to various mission and vehicle parameters, and other criteria to be defined in the early part of this effort.
STATUS:	Terminated
SD ENGINEERING CONTACT:	D. Engels
DL ENGINEERING CONTACT:	B. Krieqsman
START/FINISH DATES:	2 July 1973 to 2 August 1974.
REPORTS AND MEMOS:	

1) 73-SD-126 dated 10 August 1973.

a) 23A STS Memo No. 69-73, "Entry Guidance System Evaluation-Status Report", 3 August 1973.

2) 73-SD-152 dated 23 October 1973.

a) 10E STS Memo No. 77-73, "Shuttle Entry Guidance Display & Crew Interface", 16 October 1973.

3) 73-SD-165 dated 7 December 1973.

a) 10E STS Memo No. 82-73, "Effect of SM Alinement Errors on Navigation Errors After Blackout-3B Entry Trajectory from 100 n. mi. Orbit", 15 November 1973.

4) 73-SD-170 dated 11 December 1973.

a) 10E STS Memo No. 76-73, Entry Guidance System-Performance Evaluation", 12 October 1973.

5) 73-SD-174 dated 20 December 1973.

a) 10E STS Memo No. 87-73, "Entry-Guidance-System performance Evaluation--Final Data", 3 December 1973.

b) 10E STS Memo No. 89-73, "Details of a Reference Trajectory Guidance Concept

for Shuttle Entry and Transition", 14 December 1973.

6) 73-SD-175 dated 26 December 1973.

a) 10E STS Memo No. 88-73, "Entry Guidance Sytem Performance Comparisons", 14 December 1973.

7) 74-SD-1 dated 2 January 1974.

a) 10E STS Memo No. 90-73, "Timing and Sizing Studies of Three Shuttle Entry-Guidance Algorithms", 18 December 1973.

U K :s

TASK NO. SSTD-GN&C 28

TITLE:	GN&C 6 DOF Stability Evaluation Study
OBJECTIVE:	This effort is to investigate the stability of the FCS and guidance during the entry phase of the Shuttle landing. Existing simulations of the GN&C systems will be used and modified as required to support this effort.
STATUS:	Completed
SD ENGINEERING CONTACT:	D. Engels
DL ENGINEERING CONTACT:	G. Levine/D. Fraser
START/FINISH DATES:	15 June 1973 to 15 November 1973.
REPORTS AND MEMOS:	1) 74-SD-2 dated 3 January 1974.

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

U K :s

TASK NO. SSTD-GN&C 29

TITLE:	One-Way Doppler Navigation Performance for Various Mission Phases.
OBJECTIVE:	This effort is an extension of SSTD-GN&C 10 (Use of Transponder on Ground Tracking for IMU Calibration and Alignment during Boost and Insertion) to include one-way doppler data for Shuttle navigation during all mission phases.
STATUS:	Completed
SD ENGINEERING CONTACT:	D. Engels
DL ENGINEERING CONTACT:	B. Kriegsman/G. Muller
START/FINISH DATES:	4 June 1973 to 10 February 1974.
REPORTS AND MEMOS:	1) 73-SD-102 dated 8 June 1973.

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

2) 73-SD-106 dated 26 June 1973.

a) CSDL Memo to M. Madden from E. Muller, "One-Way Doppler Model", 26 June 1973.

3) 73-SD-121 dated 1 August 1973.

a) 23A STS Memo No. 65-73, "Boost-Phase Navigation Studies With One-Way Doppler and IMU Data-New Sensors and Acquistion Models", 1 August 1973.

4) 73-SD-134 dated 21 August 1973.

a) Data transmitted to R. Loeliger, July 27, 1973.

b) Data transmitted to R. Loeliger, August 1, 1973.

c) Memo to R. Loeliger from E. Muller dated 3 August 1973, "Doppler Study (TD No. 29)-Ground Station Performance".

d) Data transmitted to R. Loeliger, August 7, 1973.

5) 73-SD-136 dated 5 September 1973.

a) CSDL Memo to R. Loeliger from E. Muller/ P. Kachmar, "Additional Results for

Doppler Study (TD29), 4 September 1973.

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.

U K :s

TASK NO. SSTD-GN&C 30

TITLE:	Appendix to the Requirement Formulation Document (RFD)
OBJECTIVE:	The appendix to the Requirements Formulation Document is to contain the algorithms that define the GN&C equations for the Space Shuttle. It is requested that CSDL determine procedures, quidelines and checklists that will serve as an aid to the documentation and verification of the RFD.
STATUS:	Completed
SD ENGINEERING CONTACT:	L. McGaha
DL ENGINEERING CONTACT:	M. Hamilton
START/FINISH DATES:	1 August 1973 to 14 September 1973.
REPORTS AND	

MEMOS:

1) 73-SD-131 dated 17 August 1973.

   a) CSDL Preliminary Report E-2793, "Higher Order Software Requirements", August 1973.

2) 73-SD-144 dated 14 September 1973.

   a) CSDL Report E-2793, "Higher Order Software Requirements", August 1973.

U K :s

TASK NO. SSTD-GN&C 31

TITLE: GN&C System Fault Detection, Isolation and Recovery (FDIR) Study

OBJECTIVE: 1) Review crew safety and mission success reliability requirements and determine the resulting redundancy management requirements on the GN&C System FDIR.

2) Conduct an initial evaluation of possible FDIR concepts for the overall GN&C system level. The current GN&C baseline and its operating modes will be used as the basis of this study.

3) Develop a preliminary FDIR design outline for the overall GN&C system.

STATUS: Complete

SD ENGINEERING CONTACT: R. Ellison

DL ENGINEERING CONTACT: G. Edmonds

START/FINISH DATES: 27 August 1973 to 5 November 1973.

REPORTS AND MEMOS:

1) 73-SD-140 dated 7 September 1973.
   a) Introlab Memo No. 10J-8-73, "Augmented Coverage Matrix", 27 August 1973.
   b) Intralab Memo No. 10J-11-73, "Crew Safety Probability Impact of Combining Data from all Redundant Elements rather than Designating a Prime Element", 31 August 1973.
2) 73-SD-155 dated 30 October 1973.
   a) Digital Development Memo No. 773, Rev. 1, "The Effect of Shuttle Flight Computer Failures", October 5, 1973.
   b) Introalab Memorandum No. 10J-20-73, "Proposed Combined Optics IMU FDI for Costing Flight", 15 October 1973.
3) 73-SD-157 dated 8 November 1973.
   a) CSDL Report R-733, "Space Avionics-A Redundant IMU On-Board Checkout and Redundancy Management System", September

1973.

b) ISS Memo No. 73-112, "Multiple IMU 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-GN&C 32

TITLE: Boost Aborts-Powered Flight Guidance Phase

OBJECTIVE: 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 define the requisite guidance policies.

CSDL will perform studies on the powered portion of once around and RTLS aborts including off-nominal vehicle effects. Powered abort guidance 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.

STATUS: Completed

SD ENGINEERING 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	MEMOS:	

U K :s

TASK NO. SSTD-GN&C 33

TITLE: Software Requirements Documentation Support

OBJECTIVE: Assist Rockwell in the review of Functional Software Documentation and suggest formats and organization for such documentation. CSDL will participate in the generation of functional requirements and algorithm selection and specification under Rockwell direction for inclusion in the functional software requirements documents. This effort will include a review of possible documentation organization consistent with the software program structuring concepts being proposed for the Shuttle Avionics System.

STATUS: Completed

SD ENGINEERING
CONTACT: L. McGaha

DL ENGINEERING
CONTACT: G. Levine/M. Hamilton

START/FINISH 15 October 1973 to

DATES: 15 October 1973 to 20 February 1974.

REPORTS AND MEMOS:

1) 73-SD-167 dated 10 December 1973.
   a) CSDL Memo to L. McGaha from G. Levine, "Review of Software Requirements Document Book I Volume III, 2 November 1973 Issue", dated 6 December 1973.

2) 73-SD-171 dated 11 December 1973.
   a) CSDL Report No. P-017, "An Example of Algorithm Comparison Using Higher Order Software Criteria", 6 December 1973.
   b) CSDL Report No. P-019, A Discussion of Higher Order Software Concepts As They Apply to Functional Requirements and Specifications", 5 December 1973.

3) 74-SD-8 dated 5 March 1974.
   a) CSDL Document C-4034, Space Shuttle GN&C Equation Document No. 25 Rev. 1, Conic State Extropolation", February 1974.

U K :s

TASK NO. SSTD-GN&C 34

TITLE:	Deorbit Targeting
OBJECTIVE:	Perform studies aimed at defining the shuttle deorbit targeting algorithms. Studies shall include performance in face of off-nominal parameters, system failures, (i.e. OMS one engine shutdown), vehicle and subsystem constraints.
STATUS:	Cancelled
SD ENGINEERING CONTACT:	L. McGaha
DL ENGINEERING CONTACT:	T. Brand/W. Tempelman
START/FINISH DATES:	15 October 1973 to 15 February 1974.
REPORTS AND MEMOS:	1) 73-SD-153 dated 29 October 1973. a) 10E STS Memo No. 78-73, "Single and

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 Satifies the Deorbit Entry Interface Constraint," 4 March 1974.

U K :s

TASK NO. SSTD-GN&C 35

TITLE:	Adaption of TAEM and AUTOLAND Guidance to HFT
OBJECTIVE:	1) Identify HFT mission and trajectory.
	2) Identify vehicle/trajectory differences from "conventional" TAEM/A.L.
	3) Identify TAEM/A.L. test/verification data to be performed during HFT.
	4) Analyze effects of uncertainties/failures during HFT and possible remedies.
STATUS:	Discontinued
SD ENGINEERING CONTACT:	
DL ENGINEERING CONTACT:	A. Elias
START/FINISH DATES:	15 January 1974 to 2 August 1974

REPORTS AND MEMOS: Initiation of this task was awaiting official definition of mission and vehicle configuration for ALT.

U K :s

TASK NO. SSTD-GN&C 36

TITLE: Study the Feasibility of Extending TAEM to 130,000 ft.

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 (R) 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 guide 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 guidance system.

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

CONTACT: H. Ehler

DL ENGINEERING

54	CONTACT:	A. Elias
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		a) CSDL Shuttle Memo No. 10E-74-42, "Early TAEM
62		Initiation", 29 July 1974.
63		

U K :s

TASK NO. SSTD GN&C-37

TITLE:	Support of Powered Flight Guidance Working Group
OBJECTIVE:	Provide engineering analysis and simulation support needed by the Powered Flight Guidance Working Group in order to establish a unified set of baseline guidance algorithms for all exoatmospheric maneuvers; i.e. ascent to orbit, boost abort, rendezvous, orbit shaping, and deorbit.
STATUS:	Terminated
SD ENGINEERING CONTACT:	D. Engels
DL ENGINEERING CONTACT:	T. Brand
START/FINISH DATES:	1 FEBRUARY 1974 TO 2 AUGUST 1974.
REPORTS AND MEMOS:	1) 74-SD-19 dated 30 April 1974.

a) CSDL Report C-4108, "Space Shuttle G&N Equation Document No. 24 Revision 1, Unified Powered Flight Guidance, "April 1974.

2) 74-SD-22 dated 14 May 1974.

a) CSDL Shuttle Memo No. 10E-74-21, "Shuttle Deorbit Burn Performance for T/W Different from Targeted Value", 4 May 1974.

3) 74-SD-27 dated 16 July 1974.

a) CSDL Shuttle Memo No. 10E-74-29, "RTLS Fuel Depletion Throttle Algorithm for the Powered Explicit Guidance Program," 11 June 1974.

b) CSDL Document No. C-4108, "Space Shuttle G&N Equation Document No. 24, Rev. 2, Unified Powered Flight," June 1974.

4) 74-SD-30 dated 1 August 1974.

a) CSDL Shuttle Memo No. 10E-74-31, "Simplified RTLS Fuel Depletion Throttle Algorithm for PEG," 27 June 1974.

b) CSDL Shuttle Memo No. 10E-74-38, "Powered Flight Guidance Compensation for Non-Keplerian Gravity Effects During Deorbit," 17 July 1974.

5) 74-SD-31 dated 13 August 1974.

a) CSDL Shuttle Memo No. 10E-74-41, "Closed Form

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.

U K :S

TASK NO. SSTD GN&C-38

TITLE: Assessment of Navigation Sensor Errors on Shuttle PBO Footprint Capability

OBJECTIVE: Using an agreed upon Shuttle Entry Trajectory assess the footprint sensitivity to deviation in vehicle position and velocity.

Formulate correct statistical methods for assessing platform component failures at PBO footprint.

Using existing data where available, determine significant platform parameters and trajectory phases to be investigated.

Using the data from steps 1-3 above, determine allowable margins for platform errors exceeding 3 sigma.

Using a trajectory program with coupled G&N, determine curves of failure magnitude vs. the required time to detect and switch with the failure. These curves are determined by comparing

magnitude of observed trajectory error against the allowable footprint margin determined in Step 1.

STATUS: Terminated

SD ENGINEERING CONTACT: A. Madni

DL ENGINEERING CONTACT: G. Levine/B. Krieqsman

START/FINISH DATES: 1 May 1974 to 2 August 1974

REPORTS AND MEMOS:

1) 74-SD-23 dated 31 May 1974.
   a) CSDL Shuttle Memo No. 10E-74-26, "IMU FDI Requirements for Entry-and-Landing Phase, Preliminary Results", 30 May 1974.

2) 74-SD-28 dated 16 July 1974.
   a) CSDL Shuttle Memo No. 10E-74-32, "Entry and Landing Navigation Analysis", 2 July 1974.

3) 74-SD-29 dated 19 July 1974.

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

U K :s

TASK NO. SSTD-PMS 1.0

TITLE	Inflight PMS Role
OBJECTIVE:	1) Define the role of the PMS in orbiter subsystem management considering mission requirements & vehicle requirements.
	2) Review the MCC-H functions which are presently done for Apollo. Identify the candidate PMS functions as they relate to configuration, criticality and redundancy for subsystem management.
STATUS:	Complete
SD ENGINEERING CONTACT:	R. Minor
DL ENGINEERING CONTACT:	G. Silver
START/FINISH DATES:	13 November 1972 to 19 April 1973.

REPORTS AND

MEMOS:

1) 73-SD-3 dated 8 January 1973.

   a) "Submittal of Preliminary PMS Study Report-PMS 1.1," 8 January 1973.

2) 73-SD-5 dated 10 January 1973.

   a) "Submittal of Preliminary SSTD-PMS-1.2 REPORT", 10 January 1973.

3) 73-SD-26 dated 8 March 1973.

   a) "Submittal of Update SSTD-PMS-1.2 REPORT", 8 MARCH 1973.

4) 73-SD-45 dated 9 March 1973.

   a) "Submittal of Update Report for PMS 1.1 Task", 9 March 1973.

U K :s

TASK NO. SSTD-PMS 2.0

TITLE: PMS/GN&C Relationship

OBJECTIVE:

1. Develop candidate relationship between GN&C & PMS

2. Analyze the total GN&C tasks to be performed and develop candidate relationships between the two subsystems.

STATUS: Complete

SD ENGINEERING CONTACT: R. Minor

DL ENGINEERING CONTACT: G. Silver

START/FINISH DATES: 22 November 1972 to 19 April 1973.

REPORTS AND MEMOS:

1) 73-SD-9 dated 1 February 1973.

   a) "Submittal of Preliminary PMS 2.0 Task Report", dated 1 February 1973.

2) 27-SD-54 dated 26 March 1973.

   a) "Submittal of Update Report PMS 2.0 Task", dated 26 March 1973.

U K :s

TASK NO. SSTD-PMS 3.0

TITLE: PMS Phasing Alternatives

OBJECTIVE: Using data developed in Tasks 1 & 2, develop PMS alternatives

STATUS: Completed

SD ENGINEERING CONTACT: R. Minor

DL ENGINEERING CONTACT: G. Silver/T. Lawton

START/FINISH DATES: 2 January 1973 to 2 April 1973

REPORTS AND MEMOS:

1) 73-SD-33 dated 21 February 1973.
   a) "SSTD-PMS 3.0, Preliminary Report Submittal", dated 21 February 1973.

U K :s

TASK NO. SSTD-PMS 4.0

TITLE: Definition of Functional Software Concept for the PMS Function

OBJECTIVE: Define a software concept for the PMS (non-GNC) using the PMS concept defined in previous SSTD-PMS tasks 1 thru 3. Consider and work with the HAL definition and evaluation teams to define needed HAL language statements which might be PMS unique.

Preliminary output shall include a general description of the concept and general flow diagrams in a detail sufficient for the subsystem designers and software teams to understand the concept.

Update outputs shall include more detailed descriptions of the concept and flow diagram blocks, as well as more detailed flow diagrams and descriptions.

A report on HAL language suitably shall also be generated after proper consultation with the HAL team.

NAAD/RI shall support this task by providing subsystem functional path definitions and related measurement priority designations.

STATUS: Completed

SD ENGINEERING CONTACT: W. Harris

DL ENGINEERING CONTACT: G. Silver

START/FINISH DATE: 6 April 1973 to 27 August 1973

REPORTS AND MEMOS:

1) 73-SD-96 dated 29 May 1973.
   a) Submittal of Initial Report on PMS 4.0.

2) 73-SD-111 dated 16 July 1973.
   a) Submittal of Update Report of PMS Task 4.0.

U K :s

TASK NO. SSTD-PMS 5.0

TITLE: Define a Possible PMS Annunciation Concept

OBJECTIVE: Define in 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 to understand the concept.

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.

STATUS: Completed

SD ENGINEERING CONTACT: W. Harris

DI ENGINEERING CONTACT: G. Silver/K. Goodwin

START/FINISH DATES: 7 May 1973 to 27 August 1973.

REPORTS AND MEMOS:

1) 73-SD-104 dated 18 June 1973.
   a) Submittal of Initial Report of PMS Task 5.0.

2) 73-SD-119 dated 31 July 1973.
   a) Submittal of Update Report of PMS Task 5.0.

U K :s

TASK NO. SSTD-PMS 6.0

TITLE: Continuation of SSTD PMS 1.1, 1.2, 2.0 and 3.0

OBJECTIVE: The tasks previously worked as PMS 1.1, 1.2, 2.0, and 3.0 will be continued on a low level as required basis.

The effort will include, for example, further definitions of the consumables management and trend analysis capabilities.

Effort is expected to be dependent upon configuration changes, and/or requirements updates as defined by NAAD/FI.

STATUS: Completed

SD ENGINEERING CONTACT: W. Harris

DL ENGINEERING CONTACT: G. Silver

START/FINISH

DATES: 6 April 1973 to 7 September 1973.

REPORTS AND MEMOS:

1) 73-SD-137 dated 31 August 1973.
   a) Submittal of Consumables Management Portion of PMS Task 6.0.

2) 73-SD-139 dated 7 September 1973.
   a) Submittal of Update Report PMS Task 3.0.

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