INERTIAL GUIDANCE
SYSTEM
IBM RESPONSIBILITIES

- DESIGN, TEST, PROVIDE
  - DIGITAL COMPUTER
  - MANUAL DATA INSERTION UNIT
  - ΔV INDICATOR
  - AGE

- OVERALL PERFORMANCE OF INERTIAL GUIDANCE SYSTEM (M-H ASSOC CONTRACTOR)

- TECHNICAL CONTROL OF M-H WORK (VIA MAC)

- ALL INTERFACE TO DIGITAL COMPUTER (VIA MAC)

- SYSTEM HARDWARE LAB INTEGRATION OF SDC, MDIU, IMU, RADAR, ACME, CLOCK, ΔV IND, TELEM ETC

- SYSTEM ANALYSIS & SIMULATION STUDIES COMPLEMENTARY TO MAC
GUIDANCE & CONTROL FUNCTIONS

ASCENT GUIDANCE
  ▶ FOR STAGE I & STAGE II
  ▶ BACKUP FOR TITAN II GUIDANCE

RENDEZVOUS
  ▶ CATCH-UP
  ▶ CLOSED LOOP

TOUCHDOWN PREDICT
  ▶ S/C EPHEMERIS DATA
  ▶ ABORT TO PREFERRED LANDING SITE

RE-ENTRY
  ▶ GUIDED TO 60,000 ft
GEMINI
MANUAL DATA INSERTION UNITS

MANUAL DATA READOUT

- Readout of data
  - Up to 99 qtys
  - Verification of inserts
  - Various computed quantities
  - 7 digits
  - 2 address
  - 5 data

MANUAL DATA KEYBOARD

- Insertion of data by astronaut
  - Orbital parameters
  - Target coordinates
  - Time to retro-grade
  - Re-entry equation coefficients

Overall wt 4 lbs, power 4.1 w
GEMINI
INCREMENTAL VELOCITY INDICATOR

- READOUT OF INCREMENTAL VELOCITY (0-999 ft/sec)
  IN 3 BODY AXES
- USED FOR MONITORING & CONTROL OF THRUSTING MANEUVERS
- AUTOMATIC OR MANUAL SET UP
- WEIGHT 3.75 lbs, POWER 8 w
GEMINI
INERTIAL PLATFORM
**IMU FUNCTIONS**

- Attitude ref for all mission phases
- Provides three gimbal angle outputs
- Provides three integ accel ($\Delta V$) outputs
- Alignment in orbit
- Torqued at orbit rate
<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Percent</th>
</tr>
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<tbody>
<tr>
<td>Ascent Guidance</td>
<td>2700</td>
<td>21.9</td>
</tr>
<tr>
<td>Rendezvous-Catchup</td>
<td>2700</td>
<td>21.9</td>
</tr>
<tr>
<td>Touchdown Predict</td>
<td>800</td>
<td>6.5</td>
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<tr>
<td>Re-Entry</td>
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<td>26.9</td>
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<td>MDIU</td>
<td>850</td>
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<tr>
<td>I/O</td>
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<td>2.3</td>
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<tr>
<td>Go-No-Go</td>
<td>175</td>
<td>1.4</td>
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<tr>
<td>Pre-Launch</td>
<td>400</td>
<td>3.3</td>
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<tr>
<td>Common Subroutines</td>
<td>1000</td>
<td>8.2</td>
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<td><strong>Total</strong></td>
<td>12,200</td>
<td>99.3%</td>
</tr>
<tr>
<td>Total Available</td>
<td>12,288</td>
<td></td>
</tr>
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</table>
COMPUTER SOLUTION RATES

ASCENT GUIDANCE

1ST STAGE .5 SEC
2ND STAGE .8 SEC

RENADEVOUS

CATCHUP .3 SEC
RADAR DATA TRACKING COMP CYCLE .4 SEC
RADAR DATA SMOOTHING COMP CYCLE .25 SEC

TOUCHDOWN PREDICT 1 SEC

REENTRY 1 SEC

RATIO OF TOTAL PROGRAM EXECUTION TIMES

MULTIPLY 420 USEC 6.8%
DIVIDE 840 USEC .9%
REMAINING OPERATIONS (14) 140 USEC 92.3%
MTBF

<table>
<thead>
<tr>
<th>OPERATING IN ORBIT MTBF</th>
<th>MDIU</th>
<th>IVI</th>
<th>COMPUTER</th>
<th>PLATFORM</th>
<th>IMU</th>
<th>ELECTRONICS</th>
<th>POWER SUPPLY</th>
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<tbody>
<tr>
<td>17500</td>
<td>3250</td>
<td>7300</td>
<td>3120</td>
<td>1180</td>
<td>3250</td>
<td>7300</td>
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</tbody>
</table>

IGS TOTAL 500

MISSION RELIABILITY

<table>
<thead>
<tr>
<th>MODE</th>
<th>TIME (HOURS)</th>
<th>PROBABILITY</th>
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<tbody>
<tr>
<td>PRE-LAUNCH</td>
<td>2.0</td>
<td>.9959</td>
</tr>
<tr>
<td>ASCENT</td>
<td>0.1</td>
<td>.9969</td>
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<tr>
<td>RENDEZVOUS</td>
<td>5.0</td>
<td>.9897</td>
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<tr>
<td>ORBIT (ON)</td>
<td>4.0</td>
<td>.9918</td>
</tr>
<tr>
<td>ORBIT (OFF)</td>
<td>44.0</td>
<td>.9830</td>
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<tr>
<td>RE-ENTRY</td>
<td>0.5</td>
<td>.9990</td>
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</table>

MISSION RELIABILITY .9569
## IGS Physical Data

<table>
<thead>
<tr>
<th>Unit</th>
<th>Power (Watts)</th>
<th>Weight (Lbs.)</th>
<th>Volume (cu.in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>42</td>
<td>31</td>
<td>815</td>
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<tr>
<td>Platform Electronics</td>
<td>122</td>
<td>38</td>
<td>940</td>
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<tr>
<td>IGS PWR. Supply</td>
<td>76</td>
<td>43</td>
<td>881</td>
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<tr>
<td>MDRU</td>
<td>3</td>
<td>3</td>
<td>81</td>
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<tr>
<td>MDKU</td>
<td>--</td>
<td>1</td>
<td>54</td>
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<tr>
<td>IVI</td>
<td>8</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>Computer</td>
<td>95</td>
<td>58</td>
<td>2592</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>346</strong></td>
<td><strong>177</strong></td>
<td><strong>5438</strong></td>
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</table>
## Summary of Salient Computer Characteristics

<table>
<thead>
<tr>
<th>TYPE</th>
<th>General Purpose, Binary, Serial Fixed Point</th>
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<tbody>
<tr>
<td>MEMORY</td>
<td>4096 WDS (39 Bits/Wd) Random</td>
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<tr>
<td>ARITH. TIMES</td>
<td>Add, Subtract, Transfer Multiply Divide</td>
</tr>
<tr>
<td></td>
<td>140 usec 420 usec 840 usec</td>
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<tr>
<td>CLOCK RATE</td>
<td>Arith Bit Rate Memory Cycle</td>
</tr>
<tr>
<td></td>
<td>500 KC 250 KC</td>
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<tr>
<td>LOGIC SIG. LEVELS</td>
<td>0 And +8 Volts</td>
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<tr>
<td>INPUTS</td>
<td>Discretes Analog Data Channels</td>
</tr>
<tr>
<td></td>
<td>40 3 5</td>
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<tr>
<td>OUTPUTS</td>
<td>Discretes Analog Data Channels</td>
</tr>
<tr>
<td></td>
<td>20 5 4</td>
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</tbody>
</table>
MECHANICAL FEATURES

WEIGHT 56.3 #

VOLUME 1.34 CU. FT.

POWER 85 WATTS

PREDICTED MTBF 2100 HRS. PLUS

COMPONENT COUNT 11,650

CONDUCTIVE COOLING

MULTILAYER INTERCONNECTIONS

CIRCUIT MODULES 510 (103 TYPES)

EXT. STRUCTURAL USE OF MAGNESIUM & MAG. LIT.
# Components

**Silicon Planer Epitaxial Semiconductors:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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<tr>
<td>Transistors</td>
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<td>Diodes</td>
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**Resistors: CC, MF, WW**

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<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4211</td>
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**Capacitors: Glass, Cer. Tant**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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<tbody>
<tr>
<td></td>
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**Glass Delay Lines**

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<th>Quantity</th>
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<tbody>
<tr>
<td></td>
<td>5</td>
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**Magnetic Modulators**

<table>
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<th>Component</th>
<th>Quantity</th>
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<td></td>
<td>3</td>
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**400 CPS Filter**

<table>
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<tr>
<th>Component</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

**Total**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>11,650</td>
</tr>
</tbody>
</table>
LAYER BUILDUP OF TYPICAL
GEMINI MULTILAYER INTER连接
BOARD (MIB)

.0028 COPPER
15 CONDUCTIVE SURFACES

BASE MATERIAL
.012 THICK
4 LAYERS

GLASS EPOXY LAMINATE
.006 & .012 THICK

BASE MATERIAL
.004 THICK
4 LAYERS
**GEMINI AGE**

- Test Program Console
- Memory Loader
- IGS Bench Test Equipment
- MDIU/ΔV Tester
- Test Console Computer System
AGE FEATURES

- 19" Rack & Panel
- RFI Design Features
- Standard Modular System
- Heavy Duty Cabinets
- Flexible
- Mobile
RE-ENTRY
CAPABILITIES

• INITIAL CONDITIONS FROM GROUND UPDATE OR TO PREDICT MODE.
• NAVIGATION FROM RETRO.
• DISPLAY OF RETRO ΔV.
• COMPUTE DESIRED BANK ANGLE AND ACTUAL BANK ANGLE.
• COMP & DISPLAY ROLL ERROR.
• COMP & DISPLAY DOWNRANGE & CROSSRANGE ERROR.
• MAX LIFT COMMAND AT 80,000 FT.
RE-ENTRY GUIDANCE

• PRE-RETRO
  • SET INITIAL VALUES & ALIGN IMU.
  • TEST $T_R$.

• RETRO ($T_R$ TO $T_R+60$)
  • NAVIGATE INCLUDING THRUST MEASURED BY IMU.
  • NO ATTITUDE COMMANDS.
  • DISPLAY RETRO $\Delta V$.

• COAST ($T_R+60$ TO 400,000 FT. ALTITUDE).
  • CONTINUE NAVIGATION (NO IMU INPUTS)
  • NO ATTITUDE COMMANDS.

• ATMOSPHERIC (400,000 FT. ALTITUDE TO 0.4 FT/SEC² ACC.)
  • CONTINUE NAVIGATION (WITH IMU INPUTS),
  • COMMAND $B_C=0$ (MAX LIFT).
CAPABILITIES

NAVIGATION
PREPROGRAMMED COMMANDS
VEHICLE ATTITUDE CONTROL
EXPLICIT STEERING
ORBIT INSERTION
RE-ENTRY GUIDANCE (CONT.)

• ATMOSPHERIC (0.4 ft/sec\(^2\) ACC. TO 80,000 FT. ALTITUDE).
  • CONTINUE NAVIGATION (WITH IMU INPUTS).
  • COMPUTE: RANGE & HEADING TO TARGET.
  • PREDICTED RANGE TO TOUCHDOWN.
  • VEHICLE HEADING.
  • DOWNRANGE & CROSSRANGE ERRORS.

• DETERMINE \( B_e \) FROM BANK LOGIC.

• PRE-DROGUE (80,000 TO 60,000 FT. ALTITUDE)
  • COMMAND \( B_c = 0 \) (MAX LIFT).

• DROGUE CHUTE DEPLOYMENT.
**RE-ENTRY CONTROL LOGIC**

\[ D = \log_{10} \left( \frac{V_E}{a} \right) \]

\[ R_p = f[D, V_E, \gamma] \]

**WHEN** \( R_N > R_p \)

\[ B_c = f\left[ \frac{R_C}{R_N - R_p + 10} \right] \]

**WHEN** \( R_N < R_p \)

\[ R_C > 1 \quad B_c = -90^\circ \]

\[ R_C < -1 \quad B_c = +90^\circ \]

\[ -1 < R_C < 1 \quad \text{COMMAND CONSTANT ROLL} \]
RE-ENTRY SIMULATION
ACTUAL SYSTEM

ATTITUDE DISPLAY GROUP

MAN

HAND CONTROLLER

ACME

RCS

\[ \sum \]

\[ \Theta, \Psi, \Phi \]

RATES

COMPUTER

INERTIAL MEASURING UNIT

VEHICLE DYNAMICS
DYNAMIC DISPLAYS

ATTITUDE DISPLAY
ATTITUDE BALL
FDI NEEDLES

ROLL + ROLL RATE
PITCH RATE // R_DOWN
YAW RATE // R_CROSS

MAX DEFLECTION
15 DEG OR DEG/SEC
10 DEG/SEC // 100 NM
10 DEG/SEC // 12.5 NM

LONGITUDINAL ACCELERATION

ACME MODES

RATE COMMAND
DIRECT
RE-ENTRY (AUTOMATIC)
IMU SIMULATOR \( \rightarrow \) ADG

FD2 Inputs

LONG. ACC.

D/A

DACON

RTCU

7090 DPS

SDC SIMULATOR
ACME SIMULATOR
REACTION JET SIMULATOR
SIX DEGREE OF FREEDOM SPACECRAFT ENVIRONMENT

HAND CONTROLLER

DIRECT RATE COMMAND

DISCRETEs
SIMULATION INITIAL COND.

- 330,000 FT. (START OF SIMULATION)
- LANDING ENVELOPE
- RETRO

Horizontal:
330,000 FT.

VE

\[ \alpha = 20^\circ \]

\[ \gamma = 1.5^\circ \]

EARTH
Simulated Mission Profile

Altitude

330 K  Maintain 0° Roll Angle

~300 K when acceleration ≥ 0.4 ft/sec²

- Cross range and down range navigation
- Operator nulls overhead FDI
- Pitch + Yaw Rate control

80 K  Return to 0° Roll Angle

60 K  End of Simulation Run
Control Modes

1. Rate Command
2. Direct

\[ \text{Pitch\,} YAW \leq 4^\circ/\text{sec} \]
Case:
Both cross range and down range error exists

Situation:
Roll angle between
$\pm [>0^\circ < 90^\circ]$
Case: No down range error

Some cross range error > 1 mile

Situation: Roll angle ±90°
Case:

Cross Range error is zero
Some Down Range Error

Situation:
Max Lift, 0° Roll
Case:

No Down Range Error
No Cross Range Error > 1 mile

Situation:
Zero Lift
Constant Roll Rate
Summary

Cross Range & Down Range errors
±[ ±90° ]

Down Range Error
Cross Range Error = 0°
[0° roll]

No Down Range Error
Cross Range Error < 1 mile
[constant roll rate]
IGS

ASCENT GUIDANCE
MAJOR FUNCTION

BACKUP

TO PRIMARY GUIDANCE SYSTEM

FOR

CREW SAFETY
MISSION SAFETY
Y-axis oriented to geodetic vertical
X-axis parallel to orbit plane
INITIALIZATION QUANTITIES

- $\phi$ Platform azimuth with respect to East
- $\delta$ Angle between y-axis & orbit plane
- $\Delta \phi_R$ Magnitude & Direction of roll maneuver
- $V_f^*$ Final Velocity
AUTOPilot CONFIGURATION
IGS

IMU

ATTITUDE

SENSED ACCELERATION

ACTUAL GIMBAL ANGLE

CONTROL EQUATIONS

COMPUTER

ATTITUDE ERRORS

commanded gimbal angles

STAGE I
Preprogrammed Commands

STAGE II
Explicit Steering Equations

NAVIGATION
Explicit Steering

\[ \beta_p = \tan^{-1} \left[ a, + b, (t_c - t) \right] \]

Constraint Equations

**Velocity**

\[ \int_t^{t_c} a_T \sin \beta_p \, dt = -\dot{y}(t) = -A \]

**Position**

\[ \int_t^{t_c} \int_t^{t_c} a_T \sin \beta_p \, dt = h_f - h(t) - \int_t^{t_c} h'(t) \, dt = -B \]
ADDITIONAL FEATURES

• AZIMUTH & VELOCITY UPDATES
• SWITCHOVER FADE-IN
• OPTIONAL EXPLICIT YAW STEERING
TYPICAL

SLOW MALFUNCTION

ANGLE OF ATTACK

+ ERROR PITCH DOWN
- ERROR PITCH UP

PITCH ATTITUDE ERROR

Pitch Attitude Error
Primary

Pitch Attitude Error
Backup

TIME FROM LIFTOFF

0 20 40 60 80
CABIN DISPLAYS

FDI's

IVI's

Three Malfunction Lights

COMPUTER
ACCELEROMETER
ATTITUDE
CATCH-UP & RENDEZVOUS
ORBIT DATA

TARGET

HEIGHT PERIOD \(i\) 161 km 5400 s 28.5

GEMINI

HEIGHT CATCH-UP RATE 1

FAST- 87-161 5.3 28.72

SLOW-\(\approx\) 144-161 1.2 28.72

INTERCEPT- DEPENDS UPON INITIAL MANEUVER AT 270° TO GO.
Typical Rendezvous (in Plane)

Gemini at initial rendezvous thrust

Agena in circular orbit

Slow catch-up orbit

Intercept orbit

$V_0 =$ Main thrust

$V_1 =$ Vernier thrust at 210° to G.

$V_2 =$ Vernier thrust at 150° to G.

$V_3 =$ Vernier thrust 90° to G.

$V_4 =$ Vernier thrust 30° to G.

$V_5 =$ Braking and docking
IGS FEATURES

CATCH-UP

- Accepts DCS or MDIU inputs for maneuvering \((\Delta x, \Delta y, \Delta z)\)

- Solves for thrust attitude errors for FDI display

- Computes body oriented velocities to be gained for IVI display

- Monitors thrusting to count down IVI display

- Telemetry of DAS quantities
IGS FEATURES

RENDEZVOUS

- Stores Radar Time History
- Ignores Bad Radar Data
- Computes and Displays 270° Characteristic Velocity ($\Delta v_i + \Delta v_f$) Using C/W Equations
- Accepts Astronaut Decision to Rendezvous
- Predicts 250 Seconds Ahead and Re-Computes Transfer Thrust
- Solves for Thrust Attitude and Displays Errors on FDI.
- Announces the Time to Initiate Thrusts
- Predicts Radar LOS Attitude for Re-Acquisition
- Monitors Thrust to Count Down TVI
- Commands Attitude for Platform Gyrocompassing
- Commands Re-Acquisition Maneuver
- Telemetry of DAS Quantities
DATA FLOW DIAGRAM

- RADAR
- IMU
- FDI
- COMPUTER
- DCS/DAS

Δθ, ΔΨ
Δθ, ΔΨ
Δz
Δz
ΔVz, ΔVξ, ΔVζ

ΔVx = ΔVx - ΔVxo
ΔVy = ΔVy - ΔVyo
ΔVz = ΔVz - ΔVzo

MDIU
IVI
DAS QUANTITIES

1. \( \Theta_b \)
2. \( \Psi_b \)
3. \( \phi_b \)
4. \( SF_x' \)
5. \( SF_y' \)
6. \( SF_z' \)
7. \( t \)
8. \( FTAG \)
9. \( Vx_0 \)
10. \( Vy_0 \)
11. \( Vz_0 \)
12. \( \Theta_{bc} \)
13. \( \Psi_{bc} \)
14. \( T_x \)
15. \( \Delta V_{x_m} \)
16. \( \Delta V_{y_m} \)
17. \( \Delta V_{z_m} \)
18. \( R_r \)
19. \( \sin \alpha' \)
20. \( \sin \rho' \)
21. \( T_m \)
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>QUANTIZATION</th>
<th>RANGE</th>
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<tbody>
<tr>
<td>$R_r$</td>
<td>49.178 ft.</td>
<td>1,510,797 ft</td>
</tr>
<tr>
<td>$\sin a'$</td>
<td>0.001</td>
<td>0 - 0.425</td>
</tr>
<tr>
<td>$\sin r'$</td>
<td>0.001</td>
<td>0 - 0.425</td>
</tr>
<tr>
<td>$\theta_b$</td>
<td>0.036</td>
<td>0 - 360°</td>
</tr>
<tr>
<td>$\phi_b$</td>
<td>0.036</td>
<td>0 - 360°</td>
</tr>
<tr>
<td>$\psi_b$</td>
<td>0.036</td>
<td>0 - 360°</td>
</tr>
<tr>
<td>$F_{xp}$</td>
<td>0.11 ft/sec</td>
<td>$\pm 440$ ft/sec</td>
</tr>
<tr>
<td>$F_{yp}$</td>
<td>0.11 ft/sec</td>
<td>$\pm 440$ ft/sec</td>
</tr>
<tr>
<td>$F_{zp}$</td>
<td>0.11 ft/sec</td>
<td>$\pm 440$ ft/sec</td>
</tr>
<tr>
<td>$\Delta \theta_b$</td>
<td>0.0666</td>
<td>$\pm 20°$</td>
</tr>
<tr>
<td>$\Delta \phi_b$</td>
<td>0.0666</td>
<td>$\pm 20°$</td>
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<tr>
<td>$\Delta \psi_b$</td>
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<td>$\pm 20°$</td>
</tr>
<tr>
<td>$\Delta V_{x0}$</td>
<td>1 ft/sec</td>
<td>$\pm 999$ ft/sec</td>
</tr>
<tr>
<td>$\Delta V_{y0}$</td>
<td>1 ft/sec</td>
<td>$\pm 999$ ft/sec</td>
</tr>
<tr>
<td>$\Delta V_{z0}$</td>
<td>1 ft/sec</td>
<td>$\pm 999$ ft/sec</td>
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</tbody>
</table>
Typical Relative Trajectories

**In-Plane**

**Out-of-Plane**
RENDEZVOUS AT FIRST APOGEE
IGS COMPUTER
FLIGHT PROGRAM

- DESCRIBE HOW PROGRAM IS DERIVED OR MODIFIED
- DESCRIBE STEPS IN VERIFICATION OF PROGRAM FLIGHT READINESS
- REVIEW IMPACTS OF PROGRAM MODIFICATION
PROGRAM VERIFICATION

STEP 1 - SIMULATE SYSTEM MATH FLOW

• ALL DIGITAL 7090 SIMULATION
• ALL MODES DYNAMICALLY SIMULATED
• CHECK SYSTEM MATH
• DERIVE IGS MODE TESTS
PROGRAM VERIFICATION

STEP 2 - SIMULATE PROGRAM MATH FLOW

• ALL DIGITAL 7090 SIMULATION

• EMPLOYS SIMULATED GEMINI COMPUTER & ACTUAL OPERATIONAL PROGRAM

• RESULTS COMPARED WITH FORTRAN RUNS TO VALIDATE OPERATIONAL PROGRAM

• DERIVE PARAMETER TOLERANCES FOR IGS MODE TESTS
PROGRAM VERIFICATION

STEP 3 - CCTS CHECKOUT

- DEBUG IGS ACCEPTANCE TESTS, PAD TESTS, & OPERATIONAL PROGRAM

- ALL TESTS CONDUCTED WITH IGS UNITS & /OR HARDWARE SIMULATORS

- PRIMARILY A STATIC TEST AS INPUTS GENERALLY REMAIN CONSTANT
PROGRAM VERIFICATION

STEP 4 - FORMAL ACCEPTANCE

- UTILIZES IGS ACCEPTANCE TEST PROCEDURE DERIVED FROM IGS ACCEPTANCE TEST SPECIFICATION
- TESTS CONDUCTED ON DELIVERABLE IGS
- RESULTS IN DELIVERABLE PRELIMINARY FLIGHT PROGRAM
PROGRAM VERIFICATION

STEP 5 - MISSION SIMULATIONS

- DYNAMIC MISSION SIMULATION CONDUCTED ON ACTUAL IGS HARDWARE & HARDWARE SIMULATORS

- UTILIZES 7090 TO SIMULATE IGS ENVIRONMENT (e.g., S/C DYNAMICS, GRAVITY, ATMOSPHERICS)

- INPUTS & OUTPUTS VARY AS IN ACTUAL FLIGHT

- INDIVIDUAL MODES SIMULATED FIRST- THEN COMPLETE MISSION

- RESULTS IN FINALIZING OPERATIONAL FLIGHT PROGRAM
Mission simulation with hardware in the loop

- Real Time
- Closed Loop
- Realistic Missions

Purpose:

Qualify Operational Program for Flight
Simulation Components

HARDWARE

DC
  MDR
  MDK
  IVI
  IGS PS
  TRS
  ADG
  ACE Loads
  GLV Loads
  DAS
  DCS
  Radar
  IMU
  Discrete Controls & Displays

{ BB#1
  Prod#9
  Prototype

Interface Simulator

Dynamic Simulator

Mock-up

Facilities of System Simulation Laboratory

7090 DPS
Simulation Components

Software

Data Control Program
  Interface Test Routines
  Data Transfer & Conversion
  Data Storage
  Mode Control

Ascent Environment
Rendezvous Environment
Reentry Environment

Specific missions assembled from above basic programs

Data Reduction Program
Reduce, Print, Plot
DAS, Discrete, Environment Data

Revisions of previous simulations
PROGRAM MODIFICATION

- COMPUTER MEMORY IS FULL ±2%
- PROGRAM CHANGES REQUIRING ADDITIONAL INSTRUCTIONS DIFFICULT
- ATM PROPOSED AS MEANS OF INCREASING PROGRAM STORAGE CAPABILITY
- ALL PROGRAM CHANGES REQUIRE RE-VERIFICATION OF PROGRAM FLIGHT READINESS
IGS ACCEPTANCE & PAD TESTS

- VERIFY IGS PERFORMANCE AT IBM, MAC, HANGAR, & PAD

- BOTH DOCUMENTS SIMILAR & PRIMARILY CONSIST OF INTERFACE & MODE TESTS

- INTERFACE TESTS CONDUCTED FIRST

- MODE TESTS CONDUCTED PRIMARILY TO VERIFY OPERATIONAL PROGRAM

- PARAMETER TOLERANCES DETERMINED BY EQUIPMENT SPECIFICATIONS & DIGITAL 7090 SIMULATIONS