LUNAR LANDING SITE SELECTION BRIEFING

COMPILATION OF PRESENTATION MATERIAL

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
MARCH 8, 1967
LUNAR LANDING SITE SELECTION

BRIEFING

MARCH 8, 1967

COMPILATION OF PRESENTATION MATERIAL

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J. Sevier

D. C. Cheatham

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SUMMARY AND RECOMMENDATIONS

MSC DATA REQUIREMENTS FOR FUTURE MANNED LUNAR EXPLORATION PROGRAMS

ADDITIONAL TOPICS AFFECTING LANDING CONFIDENCE

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J. Sevier
STRUCTURE OF BRIEFING

- SITE SELECTION CONSIDERATIONS
  - SPACECRAFT HARDWARE AND SOFTWARE
  - OPERATIONAL CONSIDERATIONS
  - LUNAR SURFACE PROPERTIES AND ANALYSIS
- SUMMARY AND RECOMMENDATIONS FOR EARLY MISSIONS
- DATA REQUIREMENTS FOR FOLLOW-ON MANNED LUNAR MISSIONS

BASIC CONSTRAINTS ON SITE SELECTION

- LOCATED IN APOLLO ZONE (±5° LATITUDE, ±45° LONGITUDE)
  - SPACECRAFT PERFORMANCE LIMITS
  - AVAILABILITY OF ORBITER DATA
- 7° - 20° SUN ELEVATION AT LUNAR LANDING
- AT LEAST 2 DAYS BETWEEN LAUNCH ATTEMPTS
- 3 SCHEDULED LAUNCH ATTEMPTS PER MONTH
- LUNAR SURFACE PROPERTIES
Description of Problem

LM Guidance System Constraints Affecting Landing Site and Approach to Landing Site

Touchdown Point Control

D. C. Cheatham
LM DESCENT

TRANSFER ORBIT INSERTION

COASTING DESCENT

EARTH

POWERED DESCENT

SUN

LANDING RADAR

MAX ALTITUDE UPDATE THROTTLE

$h = 50,000$ FT

$V = 5500$ FT / SEC

ENGINE IGNITION

LANDING RADAR ALTITUDE UPDATE

$h = 25,000$ FT

$\theta = 71^\circ$

LR ALTITUDE UPDATE

$h = 25,000$ FT

HIGH GATE

$h = 9000$ FT

$\theta = 40^\circ$

LOW GATE

$h = 500$ FT

30 25 20 15 10 5 0

DOWNRANGE, N MI
HIGHLIGHTS OF LM LANDING APPROACH

I CREW WILL EVALUATE LANDING AREA DURING FINAL APPROACH

II CREW WILL REDIRECT GUIDANCE SYSTEM TO SUITABLE AREA

III CREW WILL SELECT TOUCHDOWN POINT AND CONTROL THE TOUCHDOWN THROUGH SEMIAUTOMATIC MODE

LM APPROACH TRAJECTORY AND GUIDANCE TARGETING FEATURES

I GUIDANCE WILL DELIVER LM TO A HIGH GATE TARGET AT A SPECIFIED VELOCITY

II APPROACH GUIDANCE FROM HIGH GATE TO LANDING POSITION WILL PROVIDE VISIBILITY AND TIME SUITABLE FOR SITE ASSESSMENT

III TERMINAL APPROACH UNDER AUTOMATIC CONTROL WILL BE COMPATIBLE WITH MANUAL CONTROL AND SWITCHOVER WILL NOT REQUIRE CONTROL TRANSIENTS
LM FINAL APPROACH AND LANDING PROFILE

- High gate: 650 ft/sec, \( \gamma \approx 14^\circ \)
- \( \approx 3 \) minutes of flight
- Window lower limit
- Low gate: 500 feet
- 34,000 feet (5.5 n mi)

LM ALTITUDE ERROR SOURCES

- 71° to 65°
- Navigation ellipsoid
- High gate
- 25,000 ft
- Terrain
- Landing site altitude uncertainty
**LM POWERED DESCENT LANDING APPROACH**

**LR ALTITUDE UPDATE**
\[ h = 25,000 \text{ FT} \]
\[ \theta = 71^\circ \]

**HIGH GATE**
\[ h = 9000 \text{ FT} \]
\[ \theta = 40^\circ \]

**LOW GATE**
\[ h = 500 \text{ FT} \]
\[ \gamma = -20^\circ \]

**LM LANDING RADAR BEAM PERSPECTIVE**

**PRIOR TO HIGH GATE**
- Flight Path
- Zero Doppler Region
- Antenna Pitched Down 24°
- Altitude Beam
- Velocity Beams

**AFTER HIGH GATE**
- Flight Path
- Zero Doppler Region
- Antenna Position 0°
OPERATING LIMITATIONS OF LM LANDING RADAR
ANTENNA POSITION = 24°

ALTITUDE BEAM INCIDENCE ANGLE, DEGREES
SIGNAL TO NOISE RATIO BOUNDARY
NOMINAL TRAJECTORY
ZERO DOPPLER BOUNDARY

LANDING RADAR WEIGHTING FACTORS
FOR ALTITUDE AND VELOCITY UPDATES

EACH AXIS SAMPLED AT 6 SEC INTERVAL

WVza WVya

.8

VELOCITY WEIGHTING FACTORS

WVza (DOWNRANGE)

.4

1600 1200 800 400

VELOCITY, FPS

0

SAMPLED EACH 2 SEC

.8

ALTITUDE WEIGHTING FACTOR

24000 16000 8000

ALTITUDE, FT

0
GUIDANCE PITCH-COMMAND SENSITIVITY TO ALTITUDE UPDATE FOR A NOMINAL TRAJECTORY

PITCH SENSITIVITY DEG/FT

$W_h = \text{ALTITUDE WEIGHTING FUNCTION}$

GUIDANCE COMMANDS FOR POWERED DESCENT

IDEAL CONDITION

TYPICAL ERROR CONDITIONS AND TERRAIN

THrust, LBS
GUIDANCE SYSTEM - LANDING RADAR - LUNAR TERRAIN INTEGRATION DESIGN PHILOSOPHY CHOICES

- Severely constrain acceptable approach terrain
- Increases site rejection
- Maintains guidance software simplicity and possibly mission planning flexibility
- Program guidance system to be insensitive to approach terrain
- Eliminates site rejection because of approach terrain
- Guidance software complexity increased - possibly impractical task
- Compromise - moderate lunar surface constraints and guidance system flexibility
- Landing radar data filtering onboard
- Simple data processing

CRITERIA FOR ASSESSING LM APPROACH GUIDANCE SENSITIVITY TO TERRAIN FEATURES

- Prior to Hi-Gate
  - Pitch angle deviation from nominal allowed +12° (ILR limitation)
- After Hi-Gate
  - Visibility margin should be at least 5° above lower window limit (landing site assessment limitation)
- Overall
  - Fuel expenditure not to exceed 60 ft/sec
VARIATION OF ACCEPTABLE CRATER SIZE WITH RANGE FROM LANDING POINT

CRATER DIAMETER, FT

CRATER DEPTH DIA = \frac{1}{6}

UNACCEPTABLE

HIGH GATE

- 2,000 FT

RANGE, FT

EFFECT OF GENERAL SLOPES ON PITCH ANGLE

PITCH ANGLE, DEGREES

AV COSTS
-1° - 1 FPS
-2° + 2 FPS
+2° + 10 FPS
+2° + 17 FPS

HIGH GATE

TIME, SECONDS
EFFECT OF GENERAL SLOPES ON LOOK ANGLE AFTER HIGH GATE

RESULTS OF TERRAIN-SLOPE GUIDANCE SYSTEM INTERFACE EVALUATION

- PRIOR TO HI-GATE
  - GENERAL UPHILL SLOPES OF 1° CAN BE TOLERATED
  - GENERAL DOWNHILL SLOPES OF 2° CAN BE TOLERATED
- AFTER HI-GATE
  - SLOPES SHOULD BE LIMITED TO ±1° TO MAINTAIN LANDING POINT DESIGNATION ACCURACY
- GENERAL
  - SENSITIVITY IS PRIMARILY RELATED TO SLOPES ENCOUNTERED JUST PRIOR TO HI-GATE - SYSTEM IS TOLERANT OF 2° SLOPES STOPPING ≈30K FT BEFORE HI-GATE
SITE SELECTION TERRAIN CRITERIA
(EXCEPTS GENERAL SLOPE)

ALTITUDE DEVIATION FROM GENERAL SLOPE LINE, FT

RANGE, FT / 10^3

NASA-S-67-1090

SITE SELECTION TERRAIN CRITERIA
(EXCEPTS GENERAL SLOPE)

ALTITUDE DEVIATION FROM GENERAL SLOPE LINE, FT

RANGE, FT / 10^3
GUIDANCE PITCH COMMAND FOR APPROACH TO SITE A-4

HIGH GATE = 9000 FT

HIGH GATE = 6000 FT
OPERATING LIMITATIONS OF LM LANDING RADAR

ANTENNA POSITION = 24°

EFFECT OF CRATERS NEAR LANDING ON LOOK ANGLE
CONTINGENCY AND FUTURE CAPABILITY PLANNING ANALYSIS

- INCREASED LANDING RADAR DATA PROCESSING
- SLOPE ESTIMATION
  - TECHNIQUES BEING EXAMINED FOR EFFECTIVENESS AND SOFTWARE COSTS
- DIFFERENT WEIGHTING FUNCTION
- DATA SMOOTHING IN GUIDANCE COMPUTER

- GUIDANCE LOGIC MODIFICATION
  - MODIFY TIME FOR GUIDANCE CONSTANT FREEZE
  - LIMITED GUIDANCE FROM CONSTANTS FREEZE POINT TO HI-GATE
  - DIFFERENT TARGETING
    - LOWER HI-GATE
    - GREATER VISIBILITY MARGIN

- RELAX CRITERIA
  - LANDING RADAR PITCH OPERATING RANGE INCREASE
  - LESS VISIBILITY MARGIN AT HI-GATE
  - USE MANUAL REDESIGNATION TO IMPROVE VISIBILITY MARGIN
Area of Site - Hardware and Navigational Uncertainties Contribution to Landing Dispersions
GEOMETRY OF POWERED DESCENT ERRORS

START OF POWERED DESCENT

NOMINAL
POWERED DESCENT ERROR SOURCES

- IMU ERRORS
  - ACCELEROMETER ERRORS
  - GYRO ERRORS
- NAVIGATION ERRORS
  - ERRORS IN LANDING SITE POSITION
  - STATE VECTOR ERRORS AT START OF POWERED DESCENT

DESCENT ORBIT INJECTION ERROR SOURCES

- ERRORS IN MAKING ΔV
  - IMU ERRORS
- STATE VECTOR ERRORS AT DESCENT ORBIT INJECTION
  - LUNAR ORBIT NAVIGATION ERRORS
LUNAR ORBIT NAVIGATION ERRORS

GOVERNED BY

- MSFN OR ONBOARD
- NUMBER OF ORBITS BEFORE DESCENT ORBIT INJECTION
- NUMBER OF LMK SIGHTINGS
  - NUMBER AND LOCATIONS OF LMKs
  - TYPE OF LMK - MAPPED / UNMAPPED
- NATURE OF ESTIMATION PROCESS
  - 6x6 OR 9x9
- NUMBER AND SPACING OF IMU ALIGNMENTS

LANDING ERROR COMPONENTS

<table>
<thead>
<tr>
<th>ERROR CONTRIBUTION</th>
<th>$\sigma_R$ FT</th>
<th>$\sigma_L$ FT</th>
<th>$\sigma_H$ FT</th>
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<tbody>
<tr>
<td>LUNAR ORBIT NAVIGATION</td>
<td>2300</td>
<td>700</td>
<td>850</td>
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<tr>
<td>DESCENT ORBIT INJECTION</td>
<td>1550</td>
<td>60</td>
<td>540</td>
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<tr>
<td>POWERED DESCENT</td>
<td>260</td>
<td>1400</td>
<td>1500</td>
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<tr>
<td>LANDING SITE</td>
<td>1380</td>
<td>1700</td>
<td>450</td>
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<tr>
<td>TOTAL (RSS)</td>
<td>3100</td>
<td>2400</td>
<td>1850</td>
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</table>

MSFN FOR THREE ORBITS WITH LSO
LANDING SITE DISPERSION ELLIPSE

PROBABILITY OF LANDING WITHIN ELLIPSE IS 99.7%

SCT LANDMARKS FOR SITE P13
1200' DIA RECOMMENDED AT 160 N MI
SCT LANDMARK SIGHTING FIELD OF VIEW LANDING SITE P13
Lunar Surface Characteristics for Touchdown

Touchdown Stability
OUTLINE OF PRESENTATION

- LANDING GEAR DESIGN CRITERIA
- LANDING GEAR DESIGN
- COMPUTER SIMULATION OF LM TOUCHDOWN
- LANDING PERFORMANCE
- CONSTRAINTS FOR SITE SELECTION
CLEARANCE CRITICAL LANDING

SOIL MODEL

\[ F = (K_1 + K_2 x + K_3 \dot{x} + K_4 \ddot{x}) A_p \]

- \( K_1 \) = Static bearing strength at surface, PSI
- \( K_2 \) = Rate of bearing strength increase with penetration, PSI/FT
- \( K_3 \) = Rate of bearing strength increase with penetration velocity, PSI/[FT/SEC]
- \( K_4 \) = Rate of bearing strength increase with penetration velocity squared, PSI/[FT/SEC]^2
- \( A_p \) = Bearing area of landing gear footpad
- \( F \) = Force on footpad from soil
CLEARANCE VERSUS BEARING STRENGTH

\[ K_1 = 15 \text{ (Rigid)} \]

\[ K_1 = 8 \]

\[ K_1 = 6 \]

\[ K_1 = 4 \]

\[ BS = K_1 + K_2 X \text{ (PSI)} \]

\[ V_V = 7 \]

\[ V_H = 4 \]

RCS ON

SELECTION OF STABILITY CRITICAL LANDING

12° SLOPE BS = 5.5 + 3.6X (PSI)

VELOCITY ANGLE = -20°

VELOCITY ANGLE = 0°

VELOCITY ANGLE = 30°

YAW ANGLE (DEG)

STABILITY MARGIN
STABILITY VS BEARING STRENGTH

99% PROBABLE VELOCITIES

- $K_1 = 15$ (RIGID)
- $K_1 = 8$
- $K_1 = 6$
- $K_1 = 4$

$BS = 7.5 + 4.2X$
$BS = 5.5 + 3.6X$

MAXIMUM TOPOGRAPHICAL SLOPE - 12°
MAXIMUM PROTUBERANCE HEIGHT - 24°
SOIL BEARING STRENGTH - SURVEYOR I EQUIVALENT

CONTRAINTS ON LM TOUCHDOWN POINT
IMPOSED BY TOUCHDOWN DYNAMICS CONSIDERATIONS
DIGITAL SIMULATION OF LM TOUCHDOWN

- SPACECRAFT CAB - 6 DEGREES OF FREEDOM
- SPACECRAFT FOOTPAD - 3 DEGREES OF FREEDOM
- CONTROL SYSTEMS
  - ATTITUDE
  - RATE OF DESCENT
- LANDING SURFACE
  - SLOPE
  - DEPRESSION, PROTUBERANCE, CURBS, TRENCHES
- OUTPUT
  - TABULAR PRINTOUT
  - GRAPHICAL
  - MOTION PICTURE

FORCES ACTING ON VEHICLE

1. SHOCK ABSORBERS
2. RCS
3. ENGINE SKIRT CRUSHING
4. ENGINE THRUST
5. LUNAR GRAVITY
LUNAR SURFACE MODEL

- SLOPE
- PROTUBERANCES AND DEPRESSIONS
- COEFF OF SLIDING FRICTION

FOOTPAD CONSTRAINTS

LANDING GEAR DETAIL

MAIN STRUT

FORCE

DEFLECTION

SECONDARY STRUT

FORCE

DEFLECTION
SIMULATION OF LM TOUCHDOWN

EXPERIMENTAL - THEORETICAL CORRELATION

- EXP STABLE
- EXP UNSTABLE
- MSC ANALYSIS
Launch Recycle and Repair

R. J. Ward
**TURNAROUND TIME**
**FOLLOWING A DECISION TO RECYCLE**

<table>
<thead>
<tr>
<th>START RECYCLE</th>
<th>OPERATIONS</th>
<th>REENTER COUNT</th>
<th>TOTAL</th>
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</thead>
<tbody>
<tr>
<td>MOVE MOBILE SERVICE STRUCTURE (T=12 HRS)</td>
<td>0</td>
<td>12 HRS</td>
<td>12 HRS</td>
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<tr>
<td>START LV CRYO LOADING (T=6 HRS)</td>
<td>6 HRS</td>
<td>12 HRS</td>
<td>18 HRS</td>
</tr>
<tr>
<td>START AUTO SEQUENCE (T=187 SEC)</td>
<td>20 HRS</td>
<td>21 HRS</td>
<td>41 HRS</td>
</tr>
<tr>
<td>AFTER S-IC IGNITION (T=7 SEC)</td>
<td>38 HRS</td>
<td>21 HRS</td>
<td>59 HRS</td>
</tr>
</tbody>
</table>

**MINIMUM SPACE VEHICLE HARDWARE RECYCLE PLAN**

- **(PAD ACCESS)**
  - SCRUB
  - ASTRONAUT EGRESS (45 MIN)
  - LV CRYO DRAIN AND H₂ PURGE BELOW 4%
  - PURGE AND DRY (6 HRS)

- MSS MOVE AND POSITION
  - (AT PAD)
  - CRYO LINE CONNECTION AND LEAK CHECK (7 HRS)
  - COUNT DOWN (EST = 14 HRS)

- SC LOX AND LH₂ TOP-OFF (14 HRS)
  - STORAGE REPLENISH (LOX, LH₂, LH₃)
ACCESS TIME FOR REPAIR
WITH 44 HOUR RECYCLE

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>START RECYCLE</th>
<th>START AUTO SEQUENCE (T-187 SEC)</th>
<th>START LV CRYO LOAD (T-6 HRS)</th>
<th>MOVE MSS (T-12 HRS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>15 HRS</td>
<td>26 HRS</td>
<td>32 HRS</td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>10 HRS</td>
<td>20 HRS</td>
<td>32 HRS</td>
<td></td>
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<tr>
<td>LM/SLA</td>
<td>10 HRS</td>
<td>20 HRS</td>
<td>32 HRS</td>
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<tr>
<td>IU/S-IUB</td>
<td>11 HRS</td>
<td>22 HRS</td>
<td>32 HRS</td>
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<tr>
<td>S-1C/S-I</td>
<td>15 HRS</td>
<td>26 HRS</td>
<td>32 HRS</td>
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SPACE VEHICLE REPAIR CAPABILITY

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<tr>
<th>LOCATION</th>
<th>44 HOURS</th>
<th>68 HOURS</th>
<th>1 TO 3 WEEKS</th>
<th>2 MONTHS</th>
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<tbody>
<tr>
<td>SPACECRAFT</td>
<td>NEGLIGIBLE</td>
<td>SIGNIFICANT</td>
<td>MAJORITY</td>
<td>DESTACK AT VAB</td>
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<tr>
<td>LAUNCH VEHICLE</td>
<td>SIGNIFICANT</td>
<td>MAJORITY</td>
<td></td>
<td>DESTACK AT VAB</td>
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<tr>
<td>GROUND SUPPORT EQUIPMENT</td>
<td>SIGNIFICANT</td>
<td>MAJORITY</td>
<td></td>
<td></td>
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<tr>
<td>MSFN - (OR WEATHER)</td>
<td>MAJORITY</td>
<td></td>
<td></td>
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</tbody>
</table>
Lighting at Lunar Landing

J. P. Loftus
LUNAR REFLECTANCE PROPERTIES

- Lunar surface acts as a retro-reflector
  - Surface brightness depends on view & sun angles
  - Luminance reaches maximum at sun angle
  - Washout phenomena occurs at zero phase angle

- Albedo variation is small
  - From 0.065 (Maria) to 0.13 (brightest rays)

- Contrast depends on local slope variations and shadows

- Measurements of reflectance properties are Earth-based and of low resolution
DETECTION RANGE
CRATERS

HORIZONTAL DETECTION RANGE, K FT

VIEW ANGLE = 38° A\(z\) = 30°
VIEW ANGLE = 14° A\(z\) = 30°
VIEW ANGLE = 14° A\(z\) = 0°
VIEW ANGLE = 38° A\(z\) = 0°

SOLAR ANGLE, DEG

SHADOWS

CONTRAST EQUATION \(C = \frac{L_T - L_B}{L_B}\)

\(\text{SUN LINE}\)
\(\text{VIEWING LINE}\)
Trajectory and Performance

J. R. Elk
OPERATIONAL CRITERIA TO BE CONSIDERED IN THE EVALUATION OF LUNAR LANDING SITES

- SPACECRAFT PERFORMANCE MARGINS
- TIME OF EARTH LAUNCH
- LIGHTING CONDITIONS AT LUNAR LANDING
- LAUNCH WINDOW CONFIGURATION
- LM COMMUNICATIONS
- APPROACH PATH LIMITS
- INJECTION COVERAGE
- DAILY LAUNCH WINDOW DURATION

ACCESSIBLE LUNAR LANDING AREA FOR FEB 1, 1968

- PACIFIC INJECTION WINDOW
- ATLANTIC INJECTION WINDOW
COMBINED ACCESSIBLE AREA

MAXIMUM VARIATION OF ACCESSIBLE AREA FOR PACIFIC INJECTION

APRIL

OCTOBER
VARIATION OF LIGHTING CONDITIONS

DATE OF LANDING, FEBRUARY

SELENOGRAPHIC LONGITUDE, ° DEG

WEST

EAST

LAUNCH DATES

SUN ELEVATION 11°

SUN ELEVATION 20°

FEB 1

FEB 2

FEB 3

FEB 4

JAN 31

JAN 30

3 4 5 6 7 8 9 10
**Performance Variations with Approach Azimuth**

![Graph showing performance variations with approach azimuth](image1)

**Annual Variation of Approach Azimuths**

![Graph showing annual variation of approach azimuths](image2)
ASSUMPTIONS

- CURRENT ΔV BUDGET
- ALLOWANCES FOR OPERATIONAL PROPELLANT RESERVES
- LM YAW IS ACCEPTABLE
- APPROACH AZIMUTH TO LANDING SITE IS WITHIN LIMITS
- NIGHT LAUNCHES ARE ACCEPTABLE (WHEN NECESSARY)
- LUNAR ORBITER II SITES P-2, P-6, P-8, P-11, P-13
### 1968 Launch Window Configuration

#### Atlantic Injections

<table>
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<th>Calendar Days of Window</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>AUG 25 - SEP 1</td>
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<td>SEP 24 - OCT 1</td>
<td>2</td>
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<td>8</td>
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<td>OCT 23 - OCT 30</td>
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#### Pacific Injection

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<td>JAN 2 - JAN 9</td>
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<td>MAR 1 - MAR 8</td>
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<td>APR 29 - MAY 6</td>
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<td>2 / 6</td>
<td>8</td>
<td>11</td>
<td>13</td>
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<td>OCT 23 - OCT 30</td>
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<tr>
<td>NOV 22 - NOV 29</td>
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<td>11</td>
<td>13</td>
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</tbody>
</table>
ACCESSIBLE AREA IN APRIL 1968

PROPOSED SITES FOR CONTINUED OPERATIONAL EVALUATION DURING 1968

<table>
<thead>
<tr>
<th>QUARTER</th>
<th>LANDING SITES</th>
</tr>
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<tbody>
<tr>
<td>JANUARY 31 - APRIL 6</td>
<td>ORBITER II 2, 6, AND 8</td>
</tr>
<tr>
<td></td>
<td>ORBITER III 9, 11, AND 12</td>
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<td>APRIL 28 - JULY 4</td>
<td>ORBITER II 2, 6, 8, 11, AND 13</td>
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<td>ORBITER III NONE</td>
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<tr>
<td>JULY 26 - OCTOBER 1</td>
<td>ORBITER II 2, 6, 8, 11, AND 13</td>
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<td>ORBITER III NONE</td>
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<tr>
<td>OCTOBER 23 - DECEMBER 28</td>
<td>ORBITER II 2, 6, 8, 11, AND 13</td>
</tr>
<tr>
<td></td>
<td>ORBITER III NONE</td>
</tr>
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</table>
OPERATIONAL CRITERIA TO BE CONSIDERED IN THE EVALUATION OF LUNAR LANDING SITES

- SPACECRAFT PERFORMANCE MARGINS
- TIME OF EARTH LAUNCH
- LIGHTING CONDITIONS AT LUNAR LANDING
- LAUNCH WINDOW CONFIGURATION
- LM COMMUNICATIONS
- APPROACH PATH LIMITS
- INJECTION COVERAGE
- DAILY LAUNCH WINDOW DURATION
General Description of Data Analysis

J. H. Sasser
CARTOGRAPHIC PRODUCTS

- TERRAIN PROFILES - LM APPROACH TRAJECTORIES
- LANDMARK IDENTIFICATION MATERIALS
- TRANS/LUNAR - TRANSEARTH NAVIGATIONAL CHARTS
- DESCENT - ASCENT PILOTAGE CHARTS
- LUNAR LANDING SITE EXPLORATION MAPS
- SIMULATOR FILM STRIPS
- RELIEF MODELS
- CHARTS FOR LANDING SITE SELECTION
- LANDING SITE PHOTOMOSAICS

CORRELATION OF SUN ELEVATION WITH APPARENT SUITABILITY OF ORBITER II SITES

<table>
<thead>
<tr>
<th>SITE</th>
<th>RATING NUMBER</th>
<th>SUN ELEVATION</th>
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</thead>
<tbody>
<tr>
<td>WEST:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-11</td>
<td>0.954</td>
<td>29.3°</td>
</tr>
<tr>
<td>P-13</td>
<td>0.902</td>
<td>19.2°</td>
</tr>
<tr>
<td>P-12</td>
<td>0.737</td>
<td>18.0°</td>
</tr>
<tr>
<td>P-10</td>
<td>0.616</td>
<td>14.1°</td>
</tr>
<tr>
<td>CENTRAL:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-8</td>
<td>0.923</td>
<td>29.8°</td>
</tr>
<tr>
<td>P-9</td>
<td>0.851</td>
<td>24.8°</td>
</tr>
<tr>
<td>P-7</td>
<td>0.772</td>
<td>20.7°</td>
</tr>
<tr>
<td>P-4</td>
<td>----</td>
<td>11.2°</td>
</tr>
<tr>
<td>EAST:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-6</td>
<td>0.947</td>
<td>29.4°</td>
</tr>
<tr>
<td>P-2</td>
<td>0.944</td>
<td>23.3°</td>
</tr>
<tr>
<td>P-5</td>
<td>0.943</td>
<td>21.9°</td>
</tr>
<tr>
<td>P-3</td>
<td>0.876</td>
<td>14.4°</td>
</tr>
<tr>
<td>P-1</td>
<td>0.868</td>
<td>16.5°</td>
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</table>
MSC CANDIDATE LANDING SITE SELECTION ACTIVITIES

LM LANDING SENSITIVITY STUDIES

COLLECTION OF EXISTING LUNAR DATA

MISSION AND SPACECRAFT CONSTRAINTS

SITE SELECTION CRITERIA

SURVEYOR

ORBITER

USGS GEOLOGIC MAPPING

DOD TOPOGRAPHIC MAPPING

SELECTION OF PRIORITY AREAS FOR APOLLO LANDING SITE ANALYSIS

COMPUTER ANALYSIS OF LUNAR ORBITER TAPES

COMBINED DATA ANALYSIS

CANDIDATE SITE SELECTION

APOLLO SITE SELECTION BOARD

CONSIDERATIONS NOT DEPENDENT ON LUNAR SURFACE PROPERTIES

CONSIDERATIONS

TRAJECTORY AND PERFORMANCE COMMUNICATIONS

LIGHTING DURING LANDING

LAUNCH RECYCLE TIME

AFFECTS THE DESIRED

LATITUDE, LONGITUDE OF SITES

LATITUDE, LONGITUDE OF SITES

NUMBER OF SITES

LONGITUDINAL SPACING OF SITES

• INPUT TO SURVEYOR / ORBITER TARGETING

• NO SURVEYOR / ORBITER DATA REDUCTION REQUIRED
CONSIDERATIONS DEPENDENT ON LUNAR SURFACE PROPERTIES

CONSIDERATIONS

LANDING DISPERSION
LANDING RADAR PERFORMANCE
TOUCHDOWN CONSTRAINTS
EROSION EFFECTS

AFFECTS THE DESIRED

SIZE AND SHAPE OF LANDING SITES
TOPOGRAPHY ALONG APPROACH PATHS
LOCAL TOPOGRAPHY WITHIN SITES
SURFACE ENGINEERING PROPERTIES
SURFACE ENGINEERING PROPERTIES

TO BE OBTAINED FROM EXISTING DATA PLUS
SURVEYOR / ORBITER DATA REDUCTION

MSC AREA
SCALE 1:1,000,000
USGS PRODUCTS

- 1:500,000 SCALE GEOLOGIC MAPS
- 1:100,000 SCALE GEOLOGIC MAPS
- 1:25,000 SCALE GEOLOGIC MAPS
- PRELIMINARY EVALUATION OF GEOLOGIC INTEREST OF CANDIDATE LANDING SITES
- DETAILED GEOLOGIC STUDIES OF SELECTED LANDING SITES
LUNAR INFORMATION FROM SURVEYOR AND ORBITER

DATA

- LM LANDABILITY
  DISTRIBUTION OF TOPOGRAPHIC SLOPES WITHIN POTENTIAL LANDING AREAS

- REGIONAL SLOPES
  DISTRIBUTION OF REGIONAL SLOPES THAT WOULD AFFECT RADAR PERFORMANCE

- SURFACE ENGINEERING PROPERTIES

- SELENOGRAPHIC POSITIONS
  LOCATIONS OF SELECTED LANDING SITES AND NAVIGATIONAL LANDMARKS

SOURCE

- ORBITER
  PRELIMINARY SCREENING
  COMPUTER ANALYSIS

- ORBITER
  PHOTOGRAMMETRIC ANALYSIS

- SURVEYOR
  POINT MEASUREMENTS

- ORBITER
  GEOLOGIC MAPPING
  PHOTO-INTERPRETATION

- ORBITER
  PHOTOGRAMMETRIC ANALYSIS
J. W. Dietrich

Lunar Geology and Soil Mechanics
SUMMARY OF LUNAR 'SOIL' CHARACTERISTICS
AT SURVEYOR I

- OVERALL STRUCTURE
  - GRANULAR, PARTICLES MAY BE POROUS

- PARTICLE SIZE
  - 1 METER TO 1 mm DIAMETER FRAGMENTS SCATTERED ON SURFACE
  - MOST OF SURFACE LAYER LESS THAN 0.5 mm
    PROBABLY 0.005 - 0.1 mm

- POROSITY
  - 70 - 80 PERCENT IN FEW CENTIMETERS NEAR SURFACE

- DENSITY
  - 0.6 - 0.7 GRAMS/cm$^3$ NEAR SURFACE
  - 1 GRAM/cm$^3$ AT DEPTH 10 - 20 cm
  - 2 - 3 GRAMS/cm$^3$ AT DEPTH 1 - 10 METERS
SUMMARY OF LUNAR 'SOIL' CHARACTERISTICS AT SURVEYOR I (CONT)

- BEARING CAPACITY, STATIC
  - $4 \times 10^5$ dynes/cm$^2$ on 25 cm diameter surface

- BEARING CAPACITY, DYNAMIC
  - $4.2$ to $6.9 \times 10^5$ dynes/cm$^2$

- COHESION
  - $10^2$ to $10^5$ dynes/cm$^2$
  - Probably $10^3$ dynes/cm$^2$

- ANGLE OF INTERNAL FRICTION
  - 30 to 55 degrees
Description of Screening with Emphasis on Orbiter II Results

A. W. Patteson
LANDING SITE ANALYSIS

- AVAILABLE LUNAR DATA
- ORBITER MISSION PLANNING
- ORBITER DATA SCREENING
- DETAILED SITE EVALUATION
- SITE SELECT

STEPS IN LUNAR ORBITER SCREENING

- CONSTRUCT LM LANDING ELLIPSES AND RADAR APPROACH TEMPLETS FROM PHOTO SUPPORT DATA
- OUTLINE REJECT AREAS ON MED RESOLUTION PHOTO
- SCAN REMAINING AREA WHERE HIGH RESOLUTION COVERAGE IS ALSO AVAILABLE
- SELECT BETTER ELLIPSE LOCATIONS WITH FAVORABLE RADAR APPROACHES. IDENTIFY OBSTACLES
- SELECT BEST ELLIPSE BASED ON LANDING AND RADAR OBSTACLES, COUNT CRATERS, AND COMPUTE 'N' NUMBER FROM MED RESOLUTION. FOR MOST FAVORABLE SITES CONTINUE EVALUATION WITH HIGH RESOLUTION PHOTOGRAPHY
- EVALUATE ELLIPSES ON HIGH RESOLUTION PHOTOGRAPHY AND COMPUTE 'N' NUMBER
where

A = an ellipse with a landing probability of 99.78%
    Dimension - 7.9 Km x 5.3 Km

B = an ellipse with a landing probability of 90%
    Dimension - 4.88 Km x 3.24 Km

C = an ellipse with a landing probability of 50%
    Dimension - 2.66 Km x 1.78 Km

where

A = the boundary outlining the radar coverage
    of approach trajectory for the entire year
SITE EVALUATION FORMULA

\[ N = \frac{0.5X}{A} + \frac{0.4Y}{B} + \frac{0.1Z}{C} \]

WHERE

\( N \) = PROBABILITY OF THE LM NOT ENCOUNTERING ANY FEATURE IDENTIFIED AS A HAZARD ON THE PHOTOGRAPH

\( X \) = (TOTAL AREA - REJECT AREA) IN THE 50% ELLIPSE

\( Y \) = (TOTAL AREA - REJECT AREA) IN THE (90% - 50%) ELLIPSE

\( Z \) = (TOTAL AREA - REJECT AREA) IN THE (99.78% - 90%) ELLIPSE

\( A \) = TOTAL AREA IN THE 50% ELLIPSE

\( B \) = TOTAL AREA IN THE (90% - 50%) ELLIPSE

\( C \) = TOTAL AREA IN THE (99.78% - 90%) ELLIPSE

LUNAR ORBITER II PRIMARY COVERAGE

[Diagram showing coverage areas marked as FAVORABLE and NONFAVORABLE]
# ORBITER II SCREENING RESULTS

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<thead>
<tr>
<th>SECTOR</th>
<th>RANK</th>
<th>SITE</th>
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<th>LOCATION</th>
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<td>MR PHOTO</td>
<td>HR PHOTO</td>
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<tr>
<td>EAST</td>
<td>1</td>
<td>6</td>
<td>.947</td>
<td>.907</td>
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<td>CENTRAL</td>
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<tr>
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<td>4</td>
<td>10</td>
<td>.616</td>
<td></td>
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</tbody>
</table>

### ORBITER II - SITE 2

![Image of Site 2](image-url)
Stereo - Photogrammetric Analysis

D. Esten
STEREOPHOTOGRAMMETRIC SLOPE DETERMINATION FROM LUNAR ORBITER PHOTOGRAPHY

- STEREOPHOTOGRAMMETRIC HEIGHTING
- DISTORTIONS: SOURCES, DETERMINATION AND CORRECTION
- LUNAR ORBITER PHOTOGRAPHY
- MEASUREMENT OF DISTORTION
- SLOPE UNCERTAINTIES

PARALLAX AND HEIGHT DETERMINATION

\[ \Delta h = \left( \frac{H}{B} \right) \left( \frac{H}{f} \right) \Delta p \]
PHOTOGRAMMETRIC TRIANGULATION

MODEL ORIENTATION
EFFECTS OF MISORIENTATION ON HEIGHTING

Model with false tip

Oriented model

h

h'

LENS DISTORTION

Undistorted grid

Pin-cusion distortion

Barrel distortion
DIFFERENTIAL SHRINKAGE PATTERN

IMAGE MOTION AND IMAGE MOTION COMPENSATION
CAMERA SHUTTERS

LENS CALIBRATION

DISTORTION, MICROMETERS

RADIAL DISTANCE, MILLIMETERS
LUNAR ORBITER SC FILM

DIRECTION OF FLIGHT

HIGH RESOLUTION

LOW RESOLUTION

70 mm FILM

60 mm

219.18 mm

279.18 mm

~11 INCHES (TYP)

FILM ADVANCE

READOUT SCHEMATIC

LINE SCAN TUBE

REVOLVING DRUM

SCANNER LENS

READOUT GATE

LIGHT COLLECTOR OPTICS

PHOTOMULTIPLIER

FILM TRAVEL - 70 mm

1/10 IN.

VIDEO SIGNAL TO VEHICLE VIDEO TRANSMITTER

VIDEO AMP
GOLDSTONE LADDER CURVES

Y-DISPLACEMENT, MICROMETERS

X-DISTANCE, MILLIMETERS

X-DISPLACEMENT, MICROMETERS

X-DISTANCE, MILLIMETERS

MISSION II RESEAU CURVES

X-DISPLACEMENTS

MICROMETERS

Y-DISPLACEMENTS

TYPICAL DISPLACEMENTS OF RESEAU POINTS ORBITER II
STEREOPHOTOGRAMMETRIC
SLOPE UNCERTAINTY ESTIMATES (CONT)

STANDARD ERROR
OF SLOPE, DEGREES

HIGH GATE

RADAR ON

MISSION 1
MISSION 2
MISSION 3

BASE, KILOMETERS
Photometric/Computer Analysis

N. W. Naugle
INTRODUCTION

OBJECTIVES OF LUNAR ORBITER / PHOTOMETRIC PROGRAM

- PROVIDE DETAIL SLOPE AND PROTUBERANCE AT LM SCALE
- CALIBRATE PHOTOGRAPHIC INTERPRETATION OF LUNAR LANDING SITES
- AID IN RAPID SCREENING OF PHOTOGRAPHS
- PROVIDE EXPERIENCE IN PICTURE DATA PROCESSING

REASONS FOR USING COMPUTER/PHOTOMETRIC TECHNIQUES

- ONLY MONOSCOPIC HIGH RESOLUTION PHOTOGRAPHY IS AVAILABLE FROM LUNAR ORBITER II
- THE PHOTOMETRIC TECHNIQUE (OR, PHOTOCLINOMETRY) IS THE ONLY KNOWN METHOD OF EXTRACTING SLOPE INFORMATION FROM MONOSCOPIC PICTURES
- CONVENTIONAL MICRODENSITOMETRY IS TOO SLOW FOR THE MASS OF DATA TO BE REDUCED
- SOME SUCCESS WITH A LIMITED AMOUNT OF RANGER DATA BY JPL (NATHAN, RINDFLEISCH, ET AL) HAS MADE THE TECHNIQUE LOOK PROMISING
SURFACE PHOTOMETRIC GEOMETRY

PHOTOMETRIC ASSUMPTIONS

- $b(g, \alpha) = \rho_0 \Phi(g, \alpha)$
- THE OUTPUT SCENE REPRODUCTION AND ITS GEOMETRY OF FORMATION CAN BE RECOVERED
- THE NORMAL ALBEDO IS CONSTANT OVER THE SCENE
LENS CENTERED COORDINATE SYSTEM

The photometric technique gives elevation data only along straight line paths in the image plane which pass through the zero phase point.
THE MAIN PROBLEMS IN USING
THE PHOTOMETRIC TECHNIQUE ON LUNAR ORBITER

- RECOVERY OF SCENE LUMINANCES
- RECOVERY OF IMAGE GEOMETRY
- ASSIMILATION OF PROFILES TO PRODUCE A
  TOPOGRAPHIC MAP
- LACK OF KNOWLEDGE ABOUT THE PHOTOMETRIC
  PROPERTIES OF THE MOON

TYING PHOTOMETRIC PROFILES TOGETHER

ASSUMPTIONS

- AVERAGE ELEVATION OF EACH RADIAL LINE WITHIN
  THE CHIT IS EQUAL TO ZERO
- LONG LINE FILTERING ALONG RADIAL LINES HELPS
  RECOVER LOCAL SLOPES
- IN THE FUTURE - POSSIBLE TO TIE STEREO CONTOURS
  TO PHOTOMETRIC PROFILES
PHOTOGRAAPHIC SUBSYSTEM OF LUNAR ORBITER

CAMERA
- FILM SUPPLY
- MIRROR
- 24 IN. FOCAL LENGTH LENS
- 3 IN. LENS

PROCESSOR
- WEB SUPPLY
- PROCESSOR DRUM
- WEB TAKE-UP
- HEAT SOURCE
- DRYER

READOUT
- VIDEO SIGNALS TO COMMUNICATIONS SYSTEM
- AMPLIFIER
- PHOTO CELL
- FILM SCANNER
- FILM TAKE-UP

FILM FORMAT

GROUND FORMAT
37.4 km
3.16 km
16.6 km
1.15 km

DIRECTION OF SPACECRAFT

EDGE DATA STRIP

70 mm
55 mm
7 mm
3 mm BLANK
2 mm TIME

FILM TRAVEL DURING PHOTOGRAPHY

9M 21.18 mm 11H 11M 13H 12M
10M 12H

FILM TRAVEL DURING READOUT

TIME OF EXPOSURE NO. 10
TIME NO. 11
TIME NO. 12

7.65 mm
2.98 mm

NASA-S-67-765
NASA-S-67-768
FILM SCANNER

- ELECTRONS
- ELECTRON GUN
- MECHANICAL SCAN MOTION
- LIGHT BEAM
- PHOSPHOROUS DRUM
- FILM TRAVEL IN READOUT
- .105 IN.
- VIDEO SIGNAL TO TRANSMITTER
- AMPLIFIER
- LIGHT COLLECTING OPTICS
- PHOTO MULTIPLIER

35mm FILM FORMAT FROM ANALOG TAPES
PRODUCED AT LANGLEY

- 35mm SPROCKET HOLES
- PLATEN EDGE NOTCHES
- TIME TRACK FROM ANALOG TAPE TO 35mm FILM
FLOW OF LUNAR ORBITER DATA

COMPUTER SYSTEM AT MSC/CAAD
DIGITIZING PHASE OF OPERATION

CONTROL PROGRAM OF THIS OPERATION

LUNAR ORBITER

TIME

VIDEO

1108 UNIVAC HARDWARE SYSTEM

TIMES TO DIGITIZE ID OF FRAMES, FRAMELETS, ETC

COMPUTER AND PROGRAM TO PRODUCE INPUT FROM RAW READINGS

CALIBRATION OF GRE

DIGITAL TAPES OF VIDEO / TIMING INFORMATION

READINGS FROM TELECORDDEX FOR FRAMELETS - FROM LSTB / LEC

HARDWARE OPERATOR

VOICE

FR 900 ANALOG TAPE FROM Langley

EDIT AND CLEANUP OF RAW DIGITAL TAPES

1108 SYSTEM

DIGITAL TAPES OF INFORMATION

EDITED DIGITAL TAPES OF INFORMATION
ANALYSIS PHASE OF OPERATION

CONTROL PROGRAM AND ANALYSIS PROGRAM

INPUT

1108 / SYSTEM

OUTPUT

35mm RECORDS OF ACTIVITY FOR CONTROL PURPOSES

EDITED DIGITAL TAPES OF VIDEO INFORMATION

CALIBRATION DATA: ACIC

LANGLEY VIA BOEING VIA EK

BOEING / LANGLEY CAMERA AND SPACECRAFT STATE VECTOR AND TRACKING DATA

PHOTOMETRIC FUNCTION

CURRENT: JPL FUTURE: ?

LUNAR SURFACE HIGH RESOLUTION COVERAGE

DIRECTION OF APOLLO ORBIT

DIRECTION OF LUNAR ORBITER FLIGHT

5.3 km x 7.9 km ELLIPSE

OVERLAP OF HIGH RESOLUTION FRAMES

12.4 km

26.8 km
SAMPLING STRATEGY
WITHIN A FRAME

APPROXIMATELY 120 CHITS PER HIGH RESOLUTION FRAME

SAMPLING STRATEGY
A CHIT

2500 LANDING SPOTS
4 ORIENTATIONS
OUTPUTS TO LUNAR SURFACE TECHNOLOGY

- Contour maps of elevations of CHITS
- Slope hazard maps of CHITS
- Protuberance hazard map of CHITS
- Cumulative distribution of slopes of CHITS
- Cumulative distribution of protuberance of CHITS
- Marginal distribution of protuberance and slope in summary form
- Number of each CHIT giving probability of good landing on the CHIT
- Slope statistics along radial lines (to USGS)
- Feedback to calibrate photo interpreters
SUMMARY AND RECOMMENDATIONS

C. H. Perrine
SUMMARY

- A SET OF SITE SELECTION CRITERIA HAVE BEEN ESTABLISHED FOR THE FIRST LUNAR LANDING MISSION
- BEST LANDING SITES AVAILABLE ARE ~ 80% - 90% HAZARD FREE WITHIN THE LANDING ELLIPSE
- SOIL PROPERTIES EQUIVALENT TO THE WORST CASE FROM SURVEYOR DATA WILL BE MORE THAN SATISFACTORY FOR LANDING STABILITY
  EROSION CHARACTERISTICS SHOULD BE TESTED ON FUTURE SURVEYOR MISSIONS
- DAYLIGHT LAUNCHES WILL BE POSSIBLE FOR APPROXIMATELY 9 MONTHS OUT OF 12
- SLOPE CHARACTERISTICS OF THE APPROACH PATH TO THE LANDING SITE WILL NOT BE DETERMINED WITH SUFFICIENT ACCURACY BY ORBITER

SITE SELECTION CRITERIA

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>QUANTITATIVE CRITERIA ESTABLISHED</th>
<th>NUMBER OF SITES EVALUATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUNAR SURFACE PROPERTIES</td>
<td></td>
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</tr>
<tr>
<td>• ELLIPSE TOPOGRAPHY</td>
<td>YES</td>
<td>5 (PRELIM)</td>
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<tr>
<td>• APPROACH PATH TOPOGRAPHY</td>
<td>YES</td>
<td>5</td>
</tr>
<tr>
<td>• ELLIPSE SOIL PROPERTIES</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>• ELLIPSE LANDMARKS</td>
<td>NO</td>
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### Site Selection Criteria (Cont)

<table>
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<th>Criteria</th>
<th>Quantitative Criteria Established</th>
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<tbody>
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<td>Operational Characteristics</td>
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<tr>
<td>• SPS Fuel Reserves</td>
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<tr>
<td>• Lighting at Landing</td>
<td>YES</td>
<td>5</td>
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<tr>
<td>• Launch Recycle Time</td>
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<tr>
<td>• LM Yaw Requirements</td>
<td>NO</td>
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<tr>
<td>• Free Return Trajectory Inclination and Landing Point</td>
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<td>5</td>
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<tr>
<td>• Translunar Injection Coverage</td>
<td>YES</td>
<td>0</td>
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<tr>
<td>• Earth Launch Window Duration</td>
<td>YES</td>
<td>5</td>
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<tr>
<td>• Lighting at Earth Launch</td>
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<td>Lunar Surface Data Availability</td>
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<tr>
<td>• High Resolution Photography</td>
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<td>4</td>
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<tr>
<td>• Oblique Views of Approach</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>• Surveyor in Area</td>
<td></td>
<td>1</td>
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</table>
SUMMARY

- A set of site selection criteria have been established for the first lunar landing mission.
- Best landing sites available are ~80% - 90% hazard free within the landing ellipse.
- Soil properties equivalent to the worst case from Surveyor data will be more than satisfactory for landing stability. Erosion characteristics should be tested on future Surveyor missions.
- Daylight launches will be possible for approximately 9 months out of 12.
- Slope characteristics of the approach path to the landing site will not be determined with sufficient accuracy by orbiter.

ALTERNATIVE SOLUTIONS TO SLOPE UNCERTAINTY

- Accept current uncertainty and develop manual control procedures after high gate to accommodate uncertainty.
- Decrease sensitivity of LM descent guidance system to slope uncertainty.
- Perform slope measurements from CSM in lunar orbit and enter values in modified LM descent guidance logic prior to descent.
RECOMMENDED B SET LANDING SITES

RESULTS OF TERRAIN-SLOPE GUIDANCE SYSTEM INTERFACE EVALUATION

- PRIOR TO HI-GATE
  - GENERAL UPHILL SLOPES OF 1° CAN BE TOLERATED
  - GENERAL DOWNHILL SLOPES OF 2° CAN BE TOLERATED

- AFTER HI-GATE
  - SLOPES SHOULD BE LIMITED TO ±1° TO MAINTAIN LANDING POINT DESIGNATION ACCURACY

- GENERAL
  - SENSITIVITY IS PRIMARILY RELATED TO SLOPES ENCOUNTERED JUST PRIOR TO HI-GATE - SYSTEM IS TOLERANT OF 2° SLOPES STOPPING ~30K FT BEFORE HI-GATE
### RECOMMENDED C SET SELECTION SCHEDULE

<table>
<thead>
<tr>
<th>CY 1967</th>
<th>CY 1968</th>
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<tbody>
<tr>
<td>2ND</td>
<td>3RD</td>
</tr>
<tr>
<td>SELECT B SET</td>
<td>▲ 1 APR</td>
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<tr>
<td>COMPLETE OPERATIONAL EVALUATIONS</td>
<td></td>
</tr>
<tr>
<td>CONFIRM SCREENING TECHNIQUE</td>
<td></td>
</tr>
<tr>
<td>SELECT C SET (SEE NOTE)</td>
<td>▲ 1 AUG</td>
</tr>
<tr>
<td>PREPARE MAPS, TRAINING AIDS AND TARGETING DATA</td>
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</tr>
<tr>
<td>SELECT LAUNCH DATES</td>
<td>▲ 1 APR</td>
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</table>

**NOTE:** ANTICIPATED C SET FORMAT

<table>
<thead>
<tr>
<th>C SET</th>
<th>CY 1968</th>
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<tbody>
<tr>
<td>EAST</td>
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<td></td>
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<tr>
<td>CENTRAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEST</td>
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</tbody>
</table>
MSC DATA REQUIREMENTS FOR FUTURE MANNED LUNAR EXPLORATION PROGRAMS

J. M. Eggleston
PHASE I OF LUNAR EXPLORATION

OBJECTIVES

- TO DETERMINE THE SURFACE CHARACTERISTICS APPLICABLE TO A MANNED LUNAR LANDING
- TO MEASURE THE LUNAR ENVIRONMENT
- TO PHOTOGRAPH FEATURES NOT VISIBLE TO THE EARTH OBSERVER
- TO MAKE FIRST ORDER EXPLORATORY MEASUREMENTS OF THE GEOPHYSICAL AND GEOLOGICAL NATURE OF THE MOON

EMPHASIS: ACQUIRE DATA TO SUPPORT EARLY MANNED LUNAR LANDINGS

PHASE I OF LUNAR EXPLORATION

FLIGHTS

<table>
<thead>
<tr>
<th>SPACECRAFT</th>
<th>COMPLETED</th>
<th>PLANNED</th>
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<tr>
<td>RANGER</td>
<td>7, 8, 9</td>
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<tr>
<td>SURVEYOR</td>
<td>1</td>
<td>(3 - 7)</td>
</tr>
<tr>
<td>ORBITER</td>
<td>1, 2, 3</td>
<td>(4, 5)</td>
</tr>
<tr>
<td>APOLLO</td>
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<td>(1, 2)</td>
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ORBITER TARGETS

ORBITER I  APOLLO ZONE - SOUTHERN SET (1M)
ORBITER II  APOLLO ZONE - NORTHERN SET (1M)
ORBITER III APOLLO ZONE - SOUTHERN SET (1M)
ORBITER IV  80% VISIBLE FACE (50 - 90M)
ORBITER V   35 - 50 SCIENCE SITES (1 - 3M)
SUBJECT TO APPROVAL
ORBITER VI  80% BACK FACE (50 - 90M)

PHOTOGRAPHIC COVERAGE FOR LUNAR ORBITER I & II

<table>
<thead>
<tr>
<th>LUNAR ORBITER</th>
<th>NUMBER OF PRIME SITES</th>
<th>COVERAGE, SQ MI</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EARTHSIDE SITES</td>
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<tr>
<td></td>
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<td>PRIME</td>
</tr>
<tr>
<td>I</td>
<td>10</td>
<td>16,000</td>
</tr>
<tr>
<td>II</td>
<td>13</td>
<td>15,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>23</td>
<td>31,000</td>
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</table>

L.O. I  L.O. II
SET A
POTENTIAL SITES

□ MARE
□ HIGHLAND
□ MOST FAVORABLE
□ LESS FAVORABLE

PHASE II OF LUNAR EXPLORATION
EMPHASIS

- SUPPORT OF SPECIFIC SCIENTIFIC MEASUREMENTS AT SPECIFIC LUNAR LOCATIONS AND THE NEAR-VICINITY, IF REQUIRED
- SURVEYING AND MAPPING OF LARGE AREAS AT SPECIFIC WAVELENGTHS IN SUPPORT OF SPECIFIC IN-SITU MEASUREMENTS
- FEASIBILITY OF USING THE MOON AS A SCIENCE AND TECHNOLOGY TEST SITE
PHASE II OF LUNAR EXPLORATION

EMPHASIS: SUPPORT OF SCIENTIFIC MEASUREMENTS

PROCESS:

STATEMENT OF OBJECTIVES

A. INSTRUMENTS REQUIRED
B. GROUPING OF INSTRUMENTS
C. MISSION MODE REQUIREMENTS

DETERMINE WHERE TO MAKE THE MEASUREMENTS ON A PRIORITY BASIS

DETERMINE SPACECRAFT AND MISSION MODE COMPATIBILITY WITH

SCIENTIFIC REQUIREMENTS

DEVELOP EXPERIMENTS, VEHICLES, AND MISSIONS WHICH ARE

REQUIRED

STATUS: WE ARE NOW IN THE DETERMINATION PHASE

APOLLO AND APOLLO APPLICATIONS

PROGRAM CONSIDERATIONS

- ESTABLISH REQUIREMENTS FOR ADDITIONAL DATA FROM SURVEYOR
  AND ORBITER, TO SELECT LANDING SITES OTHER THAN THOSE
  CONSIDERED FOR EARLY APOLLO

- PLAN LM AND SS MISSIONS TO PROCURE INFORMATION REQUIRED TO
  SUPPORT APOLLO APPLICATIONS LANDING AND ORBITAL MISSIONS

- PLAN MSC CAPABILITIES AND FACILITIES REQUIRED TO PROCESS AND
  CORRELATE DATA FROM LUNAR EXPLORATION MISSIONS

- MODIFICATIONS TO HARDWARE AND SOFTWARE TO BE CONSISTENT WITH
  SCIENTIFIC OBJECTIVES
ORBITER TARGETS

ORBITER I  APOLLO ZONE - SOUTHERN SET (1M)
ORBITER II APOLLO ZONE - NORTHERN SET (1M)
ORBITER III APOLLO ZONE - SOUTHERN SET (1M)
ORBITER IV  80% VISIBLE FACE (50 - 90M)
ORBITER V  35 - 50 SCIENCE SITES (1 - 3M)

SUBJECT TO APPROVAL

ORBITER VI  80% BACK FACE (50 - 90M)
Decision Logic for Landing Site Redesignation

H. E. Smith
VARIATION OF FOOTPRINT CAPABILITY WITH ALTITUDE

$\Delta V_c = 90 \text{ FPS}$

LUNAR LANDING SITE P-6
Erosion Effects from LM Descent Engine

R. Hutton
PHENOMENA EXAMINED

- VISCOUS EROSION
- EXPLOSIVE CRATERING
- DIFFUSED GAS ERUPTION

VISCOUS EROSION PARAMETERS

- ENGINE EXIT DIAMETER AND MACH NUMBER
- GAS RATIO OF SPECIFIC HEATS
- GAS VISCOSITY
- AZIMUTH ANGLE θ
- NOZZLE HEIGHT H
- SURFACE SLOPE γ
- LUNAR PARTICLE DIAMETER
- LUNAR SURFACE COHESION
- PARTICLE DRAG COEFFICIENT

THEORY MODIFICATIONS ACCOUNT FOR INFLUENCE OF SURFACE EROSION ON

- HEIGHT H
- AZIMUTH ANGLE θ
- SHEAR FORCES ACTING ON SOIL
**SOIL EROSION PROFILES**

**SCALED MODEL OF LM DECENT ENGINE**

\[ D = 0.08 \text{ IN.} \]
\[ D = 1 \text{ IN.} \]

**LUNAR SURFACE PARAMETER RANGES**

**SOIL PARTICLE DIAMETER, FT**

- \(10^{-5}\)
- \(10^{-4}\)
- \(10^{-3}\)
- \(10^{-2}\)
- \(10^{-1}\)

**SOIL FRICTION ANGLE, DEG**

- 10
- 20
- 30
- 40

**SOIL COHESION, PSI**

- 0
- 0.2
- 0.4
- 0.6
- 0.8

**SOIL PACKING CONCENTRATION**

- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7

**SOIL BULK DENSITY, SLUG / FT^3**

- 1
- 2
- 3
- 4
STAGNATION PRESSURE TIME HISTORY

WORST CASE LM EROSION CONTOUR PREDICTIONS
SOIL EROSION PROFILES
SURVEYOR VERNIER ENGINE

MEASURED - THEORY

EROSION DEPTH, INCHES

RADIAL DISTANCE, INCHES

TEST DD-148

NASA-S-67-1380

SOIL EROSION PROFILES
SURVEYOR VERNIER ENGINE

MEASURED - THEORY

EROSION DEPTH, INCHES

RADIAL DISTANCE, INCHES

TEST DD-149

NASA-S-67-1379
SURVEYOR VERNIER ENGINE SURFACE PRESSURE DISTRIBUTIONS

SOIL ERUPTION PARAMETERS

- Soil density
- Soil porosity
- Soil permeability
- Gas viscosity
- Gravitational acceleration
- Surface pressure and decay rate
- Initial diffused gas pressures
- Ambient pressure
SURFACE AND SUBSURFACE PRESSURE DISTRIBUTIONS

\[ \rho(r,0) = \text{SURFACE PRESSURE} \]

SOIL DEPRESSURIZATION EFFECTS
MSC TEST

PRESSURIZED SAMPLE

SAMPLE DURING DEPRESSURIZATION
MAXIMUM UPWARD SOIL DISPLACEMENT VERSUS SURFACE PRESSURE UNDER EARTH AMBIENT CONDITIONS

VARIATION OF STAGNATION PRESSURE WITH NOZZLE HEIGHT

LM DESCENT ENGINE

THRUST = 10,500 LBS

THRUST = 3000 LBS
VARIATION OF STAGNATION PRESSURE WITH NOZZLE HEIGHT

SURVEYOR VERNIER ENGINE

THrust = 105 LBS

THrust = 65 LBS

THrust = 25 LBS

PRESSURE, PSI

THrust, FEET