Cranfield
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Lunar South Pole Mission (LSPM)
Summary of the Group Design Project
MSc in Astronautics and Space Engineering
1996/97 Cranfield University

Dr Stephen Hobbs
Tom Bowling

COA report No. 0205
February 2003

College of Aeronautics
Cranfield University
Cranfield
Bedford MK43 0AL
England

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Abstract

This report is a summary of the group design project of the MSc in Astronautics and Space Engineering at Cranfield University for the year 1996/97. The project was a feasibility study of a European unmanned mission to the lunar south pole to carry out scientific study.

The mission proposed uses two spacecraft: (1) an orbiter to take images of the proposed landing site, to measure the Moon's gravitational field, and to act as a communications relay, and (2) a larger lander which carries a small rover and a crate probe. The orbiter is launched first (if gravity and image data are not already available) so that the lander's landing site can be selected. The main goal is scientific study of the permanently dark craters at the lunar south pole.

The baseline design (developed to the depth of a feasibility study) meets the stated requirements and is comparable to ESA's medium class missions (cost ~€ 300 M).

Acknowledgements

A project like this depends on input from a wide range of people, who all deserve acknowledgement. The work presented here is primarily that of the Astronautics and Space Engineering students for 1996/97. Research students and staff (Susan Jason and others) have helped significantly, as have the many industry contacts around the world who responded to students' questions patiently, and often with enthusiasm; we gratefully acknowledge their input to the project.

Contents

List of Tables

1. Introduction

This report gives a brief summary of the MSc in Astronautics and Space Engineering group design project for 1996/97, the Lunar South Pole Mission (LSPM). It is based on presentations given during the project (see Appendix A). Detailed reports by each student describing their contribution to the project are available from the School of Engineering, Cranfield University.

The presentation slides (Appendix A) form the main part of this report and give a summary of the whole project, its background, some subsystems, and the main design decisions.

Mission Objectives

The primary mission goal is

- Scientific study of the lunar south pole region.

To enable this and to maximise the probability of success for the mission as a whole, the mission comprises a simple lunar orbiter for imaging the lunar surface and to act as a communications relay, and a lander (which includes a rover and a crater probe). The main lander mission is preceded by the small orbiter which has the task of imaging proposed landing areas in detail so that the best landing site can be chosen for the lander. The orbiter also has the task of carrying out gravity field measurements so that reliable long-term orbit predictions can be made.

The mission is sized as a medium-sized mission in current ESA terminology, i.e. a cost of ~ 300 MAU (= € 300 M).

Report Structure

Following this introduction, there are brief summaries of the project's organisation (chapter 2) and a discussion of the technical work of the project (chapter 3). A full list of all the report titles is in the Bibliography. Appendix A contains copies of the slides given at the project presentation, and contains a structured list of all the slides to act as an index.

2. Project Organisation

The group project runs from October to March and accounts for 25% of the MSc course. Each student contributes about 500 hours. The project is directed by staff (Tom Bowling, Stephen Hobbs) and supported by other staff and by research students. Educationally, the project is a key element of the MSc course in that it demonstrates in a relatively realistic environment much of the material taught on the course and gives students training in the sort of project work that, for many of them, will be their working experience on graduation. The project can also be very rewarding for the real progress that is made by the students on a realistic design task.

In broad terms, the period from October to December is used to determine the top level system design, and from January to March most of the detailed design work is carried out to refine the mission baseline. Students are given responsibility for particular work packages within the project as shown in the following table.

Student	**Report title**
Afonja, Ayo	Lunar South Pole Mission: Science requirements
Carta, Salv	Lunar South Pole Mission: Attitude and control system
Coletti, Emmanuel	Lunar South Pole Mission: Electrical power system
Fahy, Will	Lunar South Pole Mission: Crater descent
Giannoulis, Tim	Lunar South Pole Mission: Configuration and structure
Inoue, George	Lunar South Pole Mission: Mission operations
Jagger, Louise	Lunar South Pole Mission: Scientific payload definition
Larrauri, Teresa	Lunar South Pole Mission: Thermal control system
Lelong, Laurent	Lunar South Pole Mission: Lunar orbit analysis
Maroothynaden, Jason	Lunar South Pole Mission: Planetary robotic exploration of the lunar south pole region
Patterson, David	Lunar South Pole Mission: Descent strategy and landing site selection
Pearson, Chris	Lunar South Pole Mission: Mission requirements and Lander main propulsion system
Piffard, Sylvain	Lunar South Pole Mission: Communication and data handling
Russel, Nick	Lunar South Pole Mission: Launch vehicle strategy
Sides, Roger	Lunar South Pole Mission: Lunar transfer trajectory: analysis and evaluation
Watson, Robert	Lunar South Pole Mission: Systems analysis

Table 1. List of individual report titles showing the individual roles within the project.

Background to the Project

LSPM builds on previous work from several areas. The group project for Astronautics and Space Engineering in 1995/96 was ELI (European Lunar Initiative), and so in several ways LSPM builds on this project. Other projects which provided information were

- MORO (Moon Orbiting Observatory) - ESA proposal
- LEDA (Lunar European Demonstration Approach) – A proposal for an ESA programme of lunar research
- EPSPEX (European Lunar South Pole Expedition) – Proposal developed at the 1996 Alpbach summer school sponsored by ESA

Table 2 lists the student reports available from the 1995/96 group project.

Student	Report
Anifantis, George	ELI Phase I: Descent Strategy and Landing
Bastin, Alec	ELI: Electrical Subsystems of a Lunar Rover
Bradford, Andrew	ELI Phase I: Lander Mechanical Subsystem: Structural Design, Landing Mechanism Design, Thermal Design
Ghafoor, Nadeem	<ELI Phase II; ELI Phase I: Imaging and Landing Guidance System>
Kalsi, Nav	(ELI: Lunar Rover) Vision, Guidance, Navigation and Hazard Avoidance
Kingston, Jenny	ELI: Rover System Engineering, Rover and Lander Operations
Kondryn, Andrew	Propulsion and Reaction Control Subsystem for the ELI Lunar Lander
Loizou, John	ELI Phase I: Lander Systems Engineering
Medley, Alec	ELI Phase I: Lander Power Supply
Nejatbakhsh, Hoss	<ELI Phase I: Launch vehicle evaluation and definition>
Seynat, Cedric	ELI Phase I: Mission Requirements, Configuration Options, Trade-off Analysis
Smith, Richard	<ELI Phases III and IV>
Thomson, Laura	ELI Phase I: Data Handling and Telemetry Subsystem
Turner, Darren	ELI: Lunar Transfer and Orbit
Warwick, Steve	ELI Stage I: Mechanical and Thermal Subsystems of the Rover
Wu, Chih-Chen	ELI: Communications Subsystem

Table 2. Student responsibilities for the 1995/96 group project, European Lunar Initiative. Braces <> indicate the area of responsibility rather than formal report title.

3. Discussion and Conclusions

The project achieved a good solution for the initial project specification. The approach taken is on the whole conservative but could be simplified if other lunar missions have taken place by the time of LSPM to provide the necessary gravity field and surface image data.

The most challenging part of the project was the design of the crater probe. Many alternative solutions have been proposed to allow useful investigation of the contents of the permanently dark (and cold) craters at the lunar south pole without damaging what could be a unique record of the solar system's history. The crater probe is probably the most original part of the project and is worthy of further study so that the costs and benefits of the different options can be better understood.

The project's main conclusion is that a European, science-led mission to the lunar south pole region is feasible. The cost of the mission is expected to be comparable to that of other medium-sized ESA missions (~€300 M).

Full details of the study are reported in the individual group project reports written by the students (available from the School of Engineering, Cranfield University). The presentation slides in Appendix A give an overview of the mission and show the various system-level options considered.

Bibliography and References

Afonja, Ayo, Lunar South Pole Mission: Science requirements. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Carta, Salv, Lunar South Pole Mission: Attitude and control system. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Coletti, Emmanuel, Lunar South Pole Mission: Electrical power system. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

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Pearson, Chris, Lunar South Pole Mission: Mission requirements and Lander main propulsion system. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Piffard, Sylvain, Lunar South Pole Mission: Communication and data handling. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Russel, Nick, Lunar South Pole Mission: Launch vehicle strategy. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Sides, Roger, Lunar South Pole Mission: Lunar transfer trajectory: analysis and evaluation. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

Watson, Robert, Lunar South Pole Mission: Systems analysis. Group Design Project report, College of Aeronautics, Cranfield University, April 1997.

ESA, LEDA – Lunar European Demonstration Approach – Assessment study final report. LEDA-RP-95-02, rev. 0, 12 June 1995.

ESA, MORO – Moon orbiting observatory – Phase A study report. ESA document SCI(96) 1, March 1996.

Spudis, P., et al, Physical environment of the lunar south pole from Clementine data: implications for future exploration of the Moon. Lunar and Planetary Science Congress, Houston, 1995.

All the individual student reports are available from the School of Engineering; contact Dr. Stephen Hobbs, Course Director, MSc in Astronautics and Space Engineering.

Ase\yr9697\GDP1996 Summary.doc, 03/02/03

Appendix A. Lunar South Pole Mission Presentation Slides

These slides were prepared for a presentation given at the end of the first phase of the project (system design) in December 1996. The remainder of the study period was largely devoted to development of the individual study areas and is documented in the individual group project reports submitted by the students.

A.1 Mission Introduction

1. TITLE PAGE
2. BACKGROUND
3. OBJECTIVES
4. MISSION OVERVIEW
5. PRESENTATION FORMAT

A.2 Scientific Background

6. SCIENTIFIC THEMES – Origin of the Moon
7. SCIENTIFIC THEMES – Origin and evolution of the lunar crust
8. SCIENTIFIC OBJECTIVES – High resolution topographical and geochemical mapping
9. SCIENTIFIC OBJECTIVES – Heat flow and temperature measurements

A.3 Design overview

10. ENGINEERING OBJECTIVES
11. ORBITER
12. LANDER
13. ROVER
14. CRATER PROBE
15. PRELIMINARY MASS BUDGET
16. LANDER MASS BUDGET
17. ORBITER MASS BUDGET

A.4 Launcher options

18. OPTIONS: ARIANE (AR44L)

A.5 Transfer orbit options

A.6 System baseline tradeoff

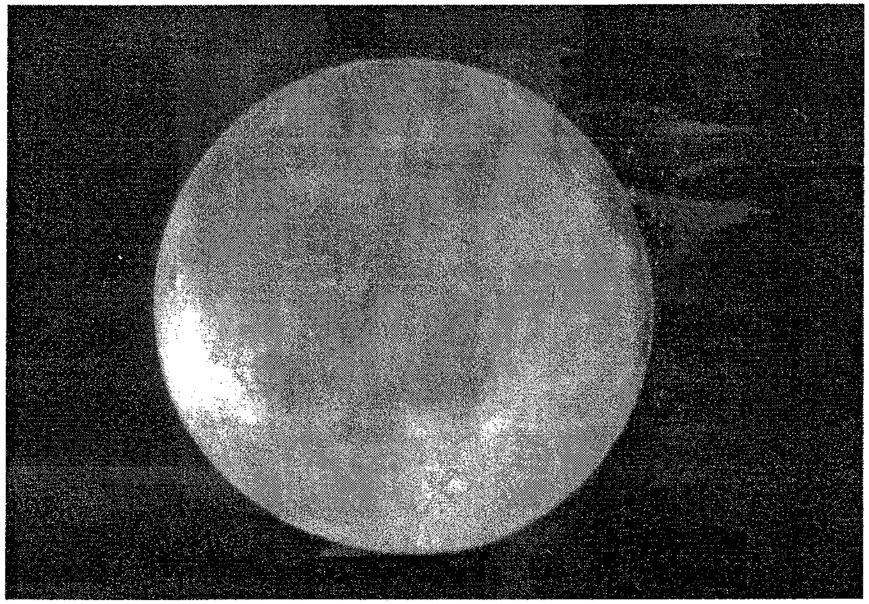
A.7 Baseline power budgets

A.8 Communications link budgets

A.9 Crater descent options

A.10 Conclusions

Lunar South Polar Mission (LSPM)



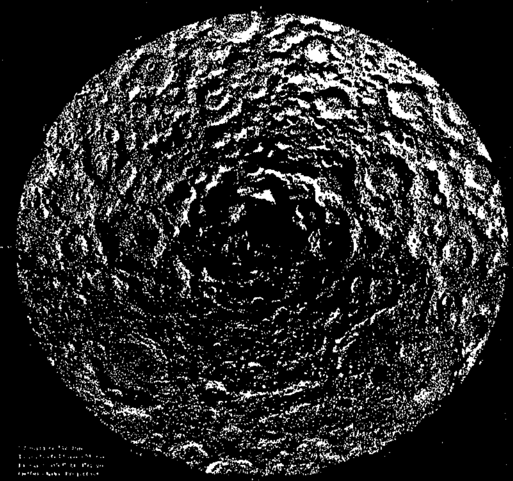
Astronautics and Space Engineering Group
Cranfield University

Background

- Mission is the first stage of a phased ESA exploration of the moon.
- Opportunities for advancements in geology, life-sciences and astronomy.
- Develop skills for further manned solar system exploration.

Objectives

- Detailed mapping around lunar south pole
- Landing within reach of south pole crater
- Develop various crater descent schemes
- Medium-sized mission (350 MAU)



Mission overview

- Orbiter and subsatellite obtain information for landing
- Lander lands within reach of largest Aitken Basin crater
- Roving vehicle to explore surface
- Lunar satellites continue mapping

Presentation format

- Science group
- Mission analysis
- Spacecraft Configuration
- Mass

- Power
- Communications
- Crater descent
- Conclusion

SCIENTIFIC THEMES

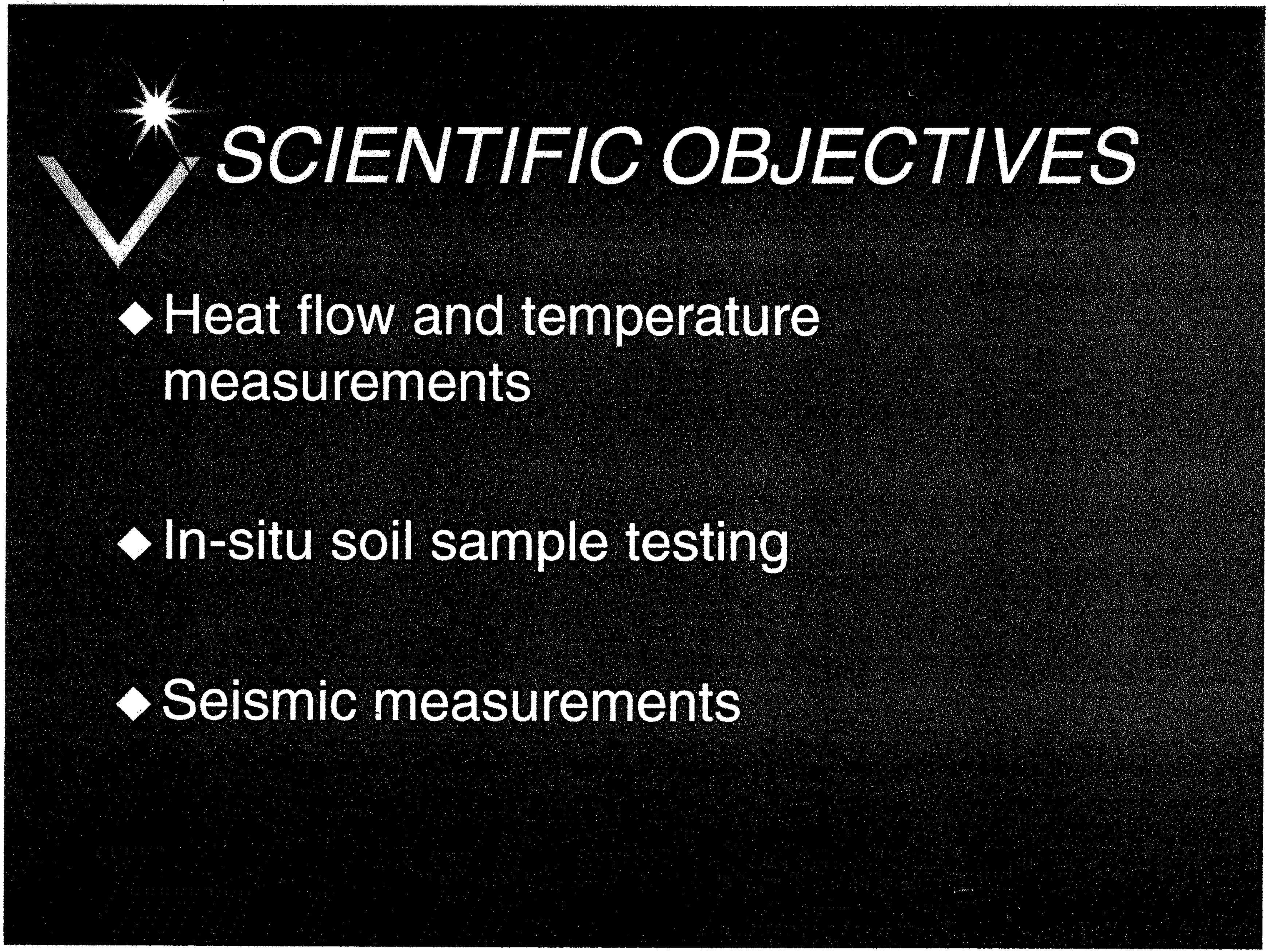
- Origin of the Moon
- History of the formation of regolith and its composition
- Distribution of the gravitational field
- Nature of local magnetic field
- Thermal evolution and internal structure

SCIENTIFIC THEMES

- Origin and evolution of the lunar crust
- Presence of water/ice in the polar regions
- Geomorphologic dichotomy between the Moon's near and far sides
- Impact processes over geological time
- Earth - Moon formation model

SCIENTIFIC OBJECTIVES

- High resolution topographical and geochemical mapping
- Local and global gravitational mapping
- Geology, morphology and mineralogy


SCIENTIFIC OBJECTIVES
◆ Heat flow and temperature measurements
◆ In-situ soil sample testing
◆ Seismic measurements

Slide 9

ENGINEERING OBJECTIVES

- Soft-land on the Moon
- Crater entry
- Preservation of lunar environment

ORBITER

INSTRUMENT	POWER (Watts)	MASS (Kg)	DATA RATE (bit/s)	PRODUCTION COMPANY/ MISSION	TIME SCALE (MONTHS)
High Resolution Stereo Camera	12	9	550 Mb/orbit	MORO	12
Ultra-violet/Visible CCD Camera	4.5	0.41		Clementine	"
Near-Infrared CCD Camera	11	1.92	98.3 kb/s	Clementine	"
Neutron Detector	2.5	3.9	0.05 kb/s	Lunar Prospector	"
Geodesy Subsatellite	0	4.7	0	MORO	2-3
Subsat equipment on orbiter	5	5	<10 Mb/orbit		
TOTAL	**30**	**19.93**			

LANDER

INSTRUMENT	POWER (Watts)	MASS (Kg)	DATA RATE (bit/s)	PRODUCTION COMPANY/ MISSION	TIME SCALE
Dust Flux Analyser	1	2.5	0.1 Kb/s	ROSETTA	Continuous
Micrometerorite Flux Counter	1.9	2.3	0.1 Gb/s	GIOTTO	Continuous
Gamma-ray Spectrometer	1	0.9	8 Kb/sample	Marsnet	10 hrs/sample
Thermal Analysis/Evolved Gas Analy:	1.5	2	1 Mb/sample	Intermarsnet	1 hour/sample
Fluxgate Magnetometer (x2)	0.3	0.3	200 Kb/day	Intermarsnet	Continuous
TOTAL	5.7	8			

ROVER

INSTRUMENT	POWER (Watts)	MASS (Kg)	DATA RATE (bit/s)	PRODUCTION COMPANY/ MISSION	TIME SCALE
Close up imager	4	0.3	512 Kb/img	Intermarsnet	6 images/stop
Panoramic Camera System (IMP)	4	2.7	86 Mb/pan	Intermarsnet	Depends on available telemetry
Alpha Proton X-ray Spectrometer	0.3	0.25	32 Kb/smp	Marsnet	10 hrs/sample
Gamma-ray Spectrometer	1	0.9	8 Kb/smp	Marsnet	10 hrs/sample
Mossbauer spectrometer	0.6	0.4	0.2 Mb/smp	Intermarsnet	10 hrs/sample
TOTAL	9.9	4.55			

CRATER PROBE

INSTRUMENT	POWER (watts)	MASS (Kg)	DATA RATE (bit/s)	PRODUCTION COMPANY/ MISSION	TIME SCALE
Thermal Array Probes	1	0.35	50 b/s	Marsnet	Continuous
Neutron Detector	0.2	0.3	32 b/smp	Marsnet	10 hrs/sample
Seismometer	0.0002	0.3	5 kbit/s	Intermarsnet	Continuous
Tiltmeter	0.08	0.07	16 bits/meas	Intermarsnet	Continuous
Mossbauer spectrometer	0.6	0.4	0.2 Mb/smp	Intermarsnet	10 hrs/sample
TOTAL	**0.8802**	**1.07**			

PRELIMINARY MASS BUDGET

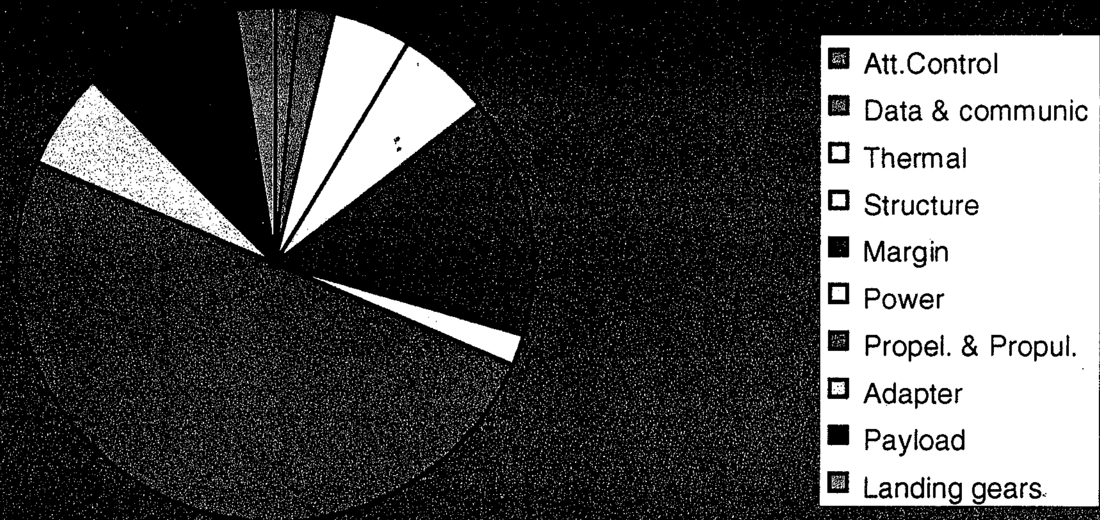
- MASS OF THE LANDER

Element	% of S/c dry mass	Mass kg
Attitude Control	1.5	30
Data & commun.	2	40
Thermal	5	100
Structure	6	120
Margin	15	300
Power	2	40
Propel. & Propul.	50	1000
Adapter	6	120
Payload	10	200
Landing gears	2.5	50
TOTAL (wet mass)	100	2000
TOTAL (dry mass)		1000

- MASS OF THE ORBITER

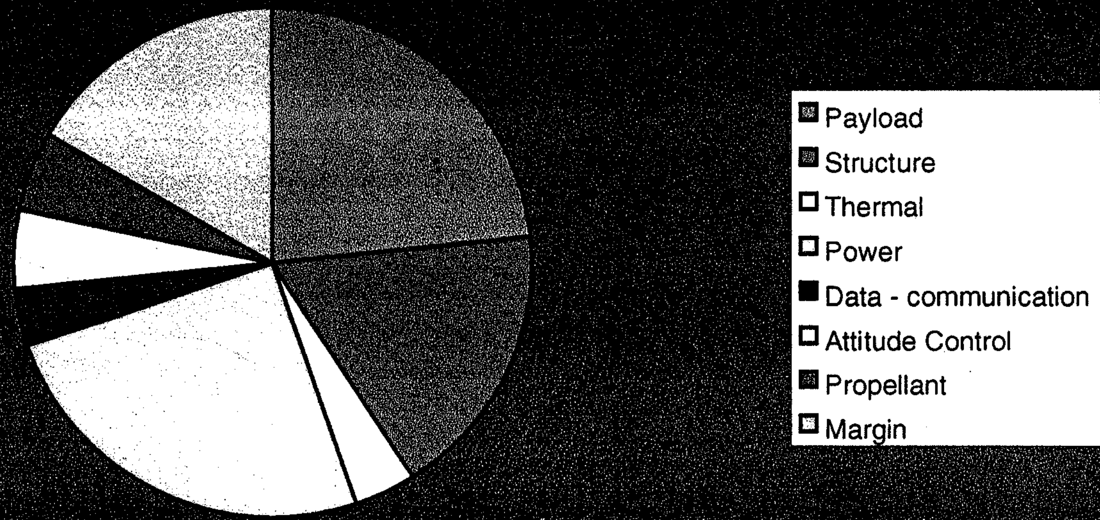
Element	% of s/c dry mass	Mass kg
Payload	28	20.5
Structure	21	15.4
Thermal	4.5	3.3
Power	30	22.0
Data - commun.	4.5	3.3
Attitude Control	6	4.4
Propellant	6	4.4
Total	100	73.2
Margin	20	14.6
Total		87.9
Subsatellite		6
Total		93.9

LANDER MASS BUDGET



- Mass estimates of each system as a % of S/C dry mass
- Considers the S/C at LLO only - no lunar transfer values included
- *Reference : AIAA 93-4743 and ELSPEX tables*

ORBITER MASS BUDGET



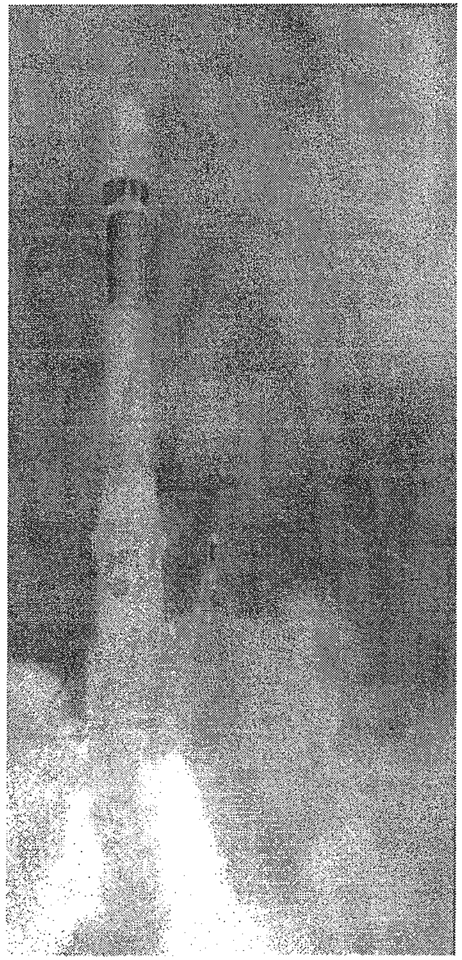
- Mass estimates of each system as a % of S/C dry mass
- Considered to be as a microsatellite
  - *Reference : Space Mission Analysis and Design*

Launch Vehicle Options

- Options
- Ariane (AR44L)
- Ariane 5 – Shared Launch to GTO
- Proton
- Taurus – combined with one of the above

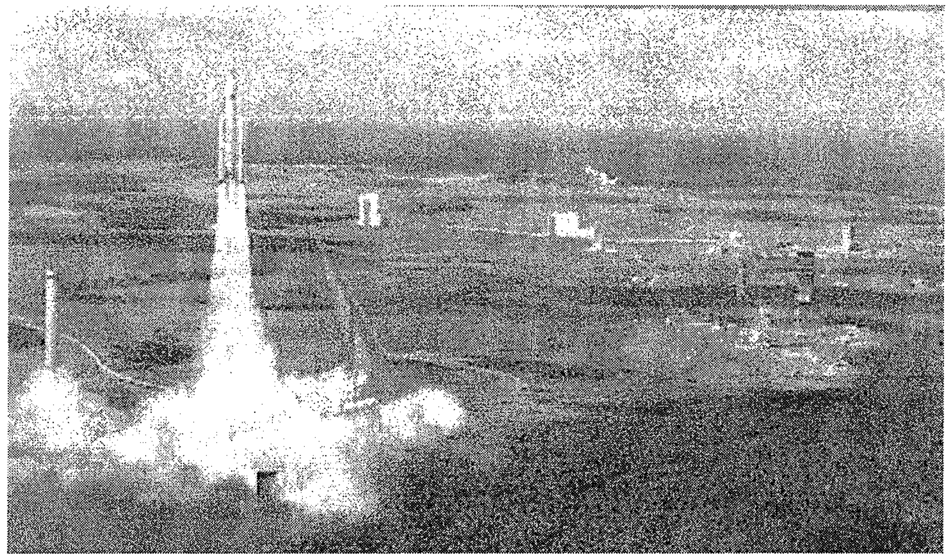
Ariane 4 (AR44L)

- Cost $90-110M
- ΔV required for LLO is 6.32 km/s.
- Final weight of spacecraft in LLO is 1280 kg.



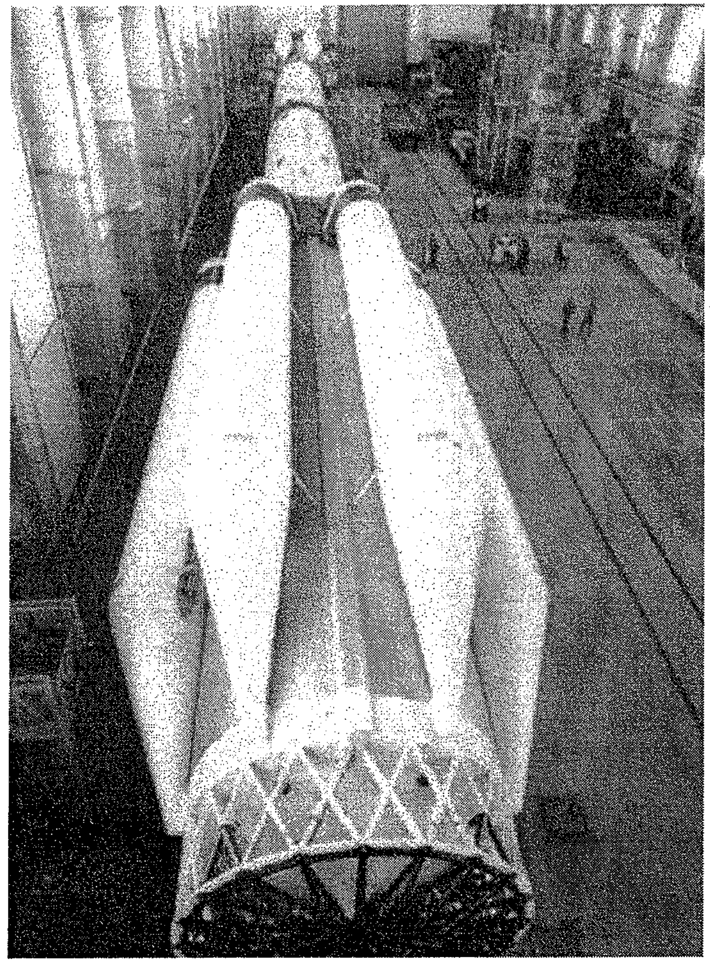
Ariane 5 (Shared launch)

- Cost $60M
- ΔV required to LLO is 2.58 km/s.
- Final weight of spacecraft in LLO is 1311 kg.



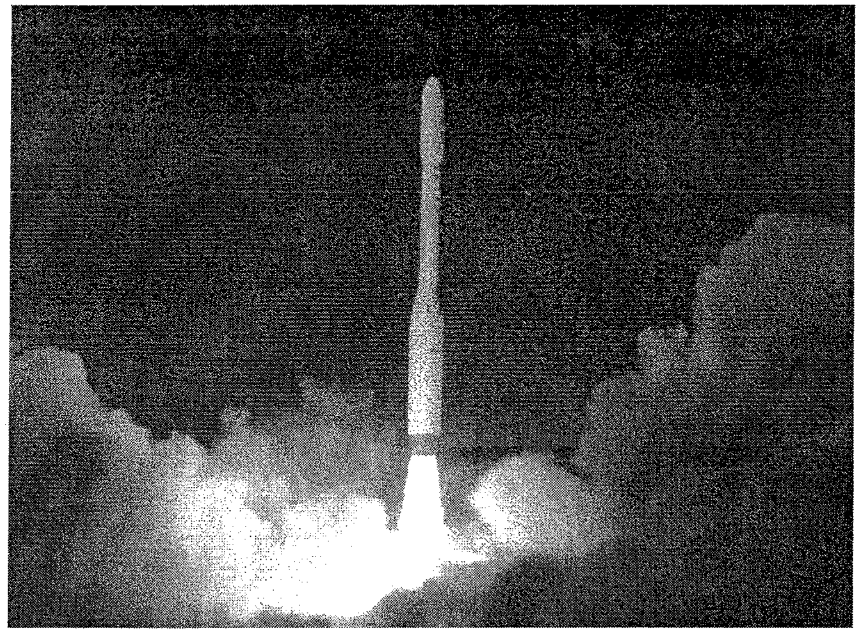
Proton

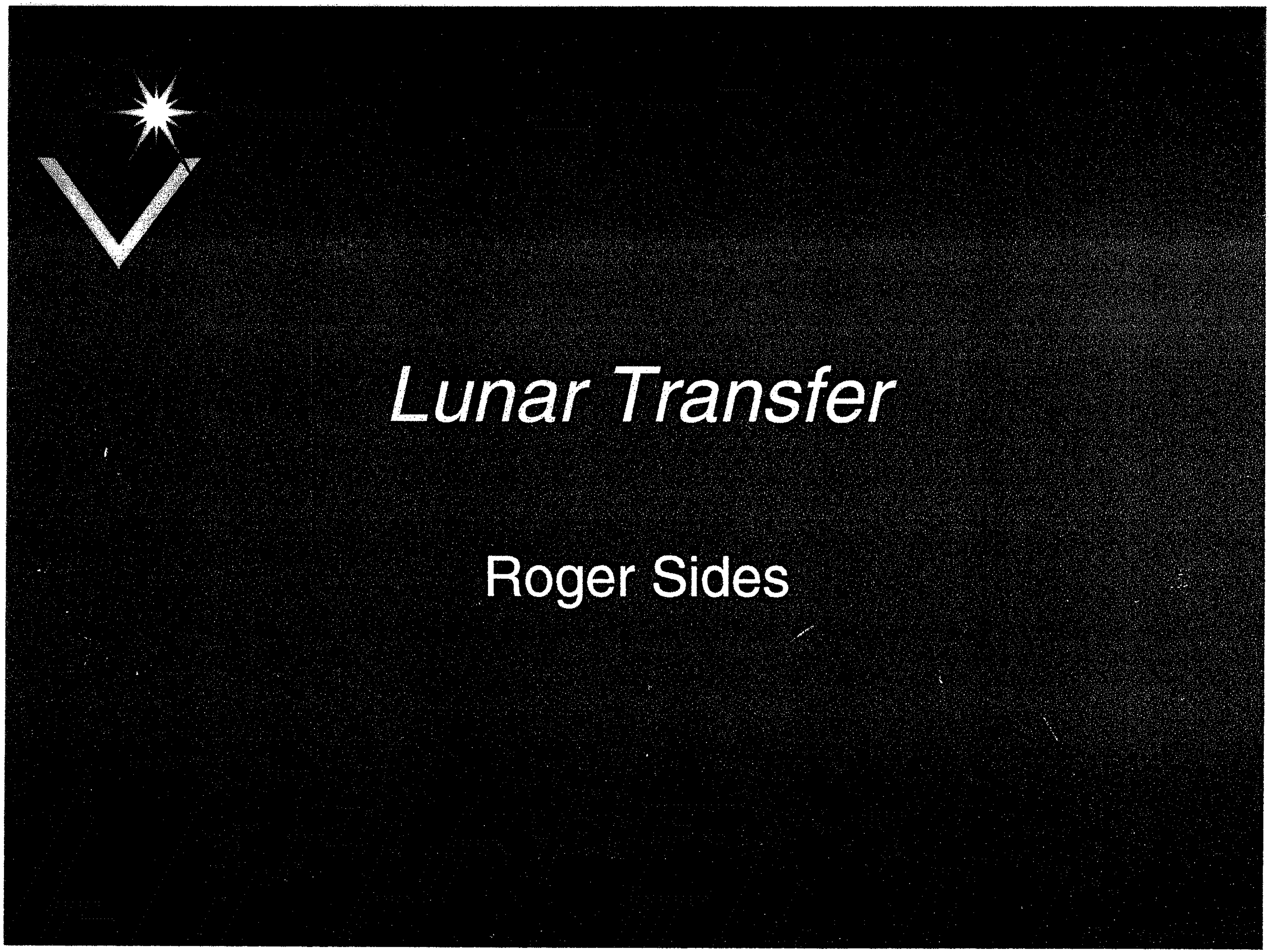
- Cost $50-70M
- ΔV required to LLO is 0.82 km/s.
- Final weight of spacecraft in LLO is 3773 kg.



Taurus

- Cost $18-20M
- ΔV required to LLO is 1.54 km/s.
- Final weight of spacecraft in LLO is 275 kg, payload size will depend on size of motor.

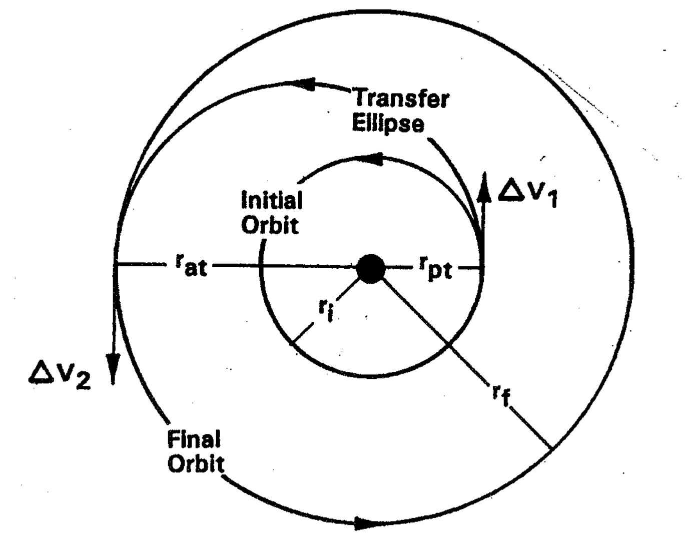




Slide 23

Hohmann Transfer

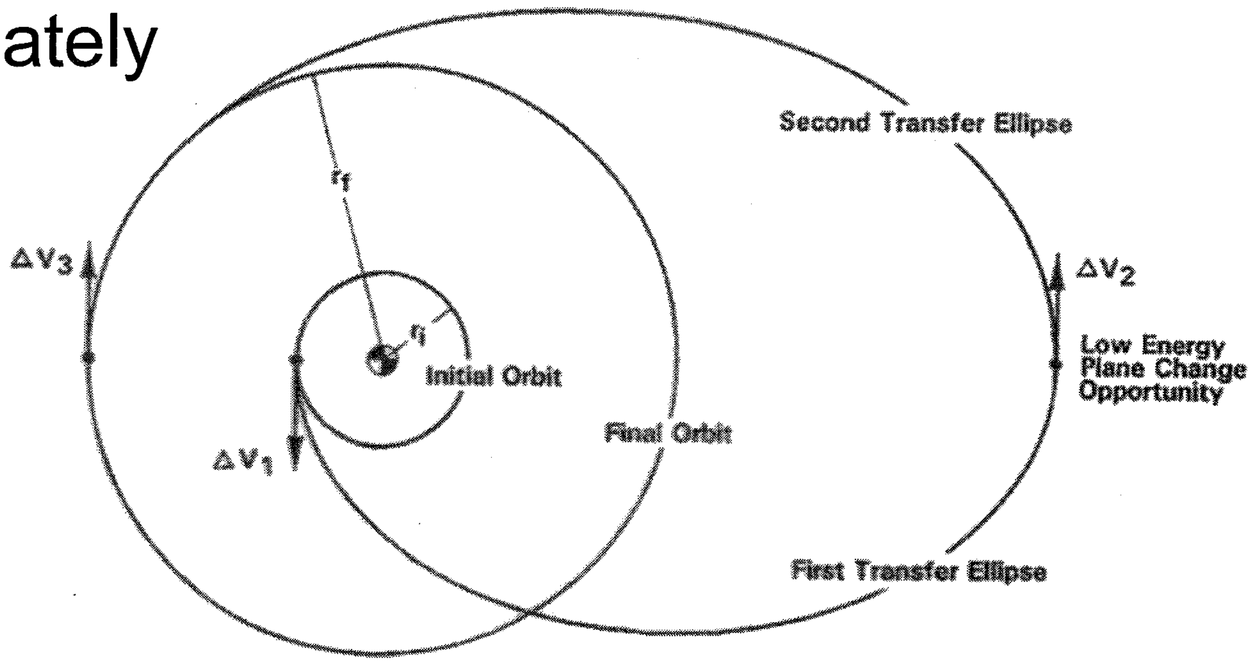
- Standard Method
- 2 Body Model
- ΔV=3.959 km/s
- Transit time, 5 days



Hohmann transfer.

Bielliptic Transfer

- ΔV=4.148km/s
- 2 Body Model
- Trip Time 4 months approximately

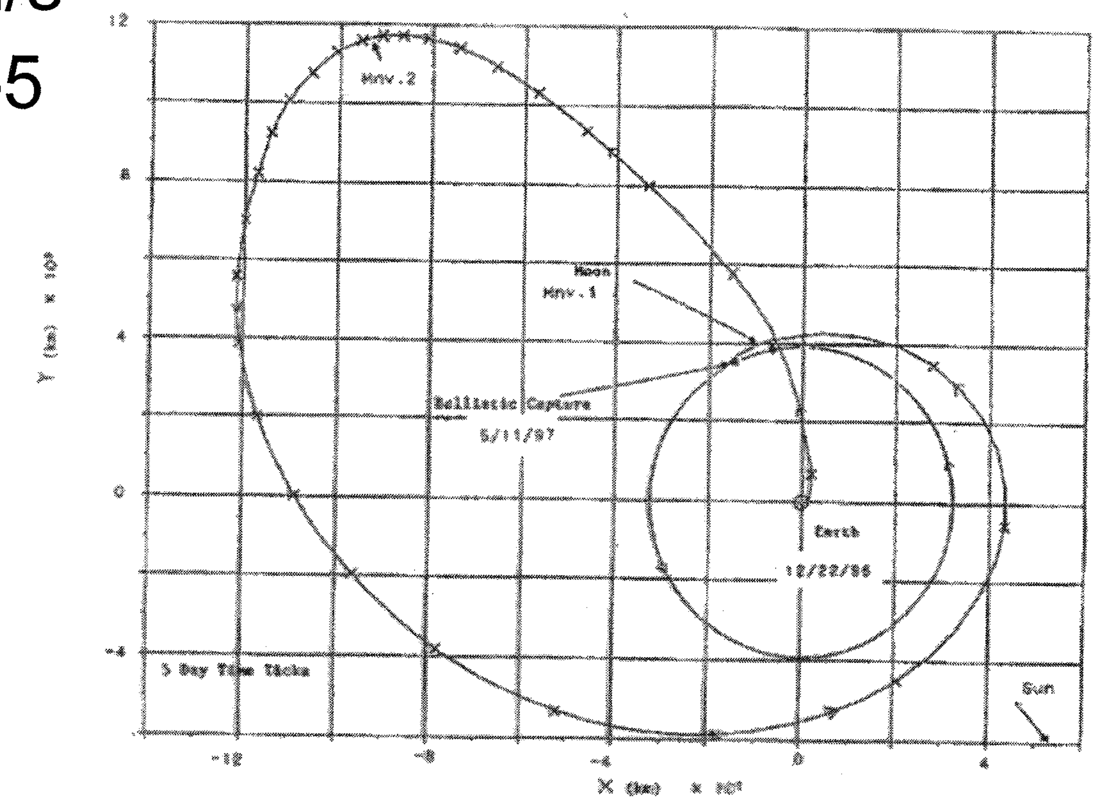


Bielliptical transfer.

Weak Stability Boundary

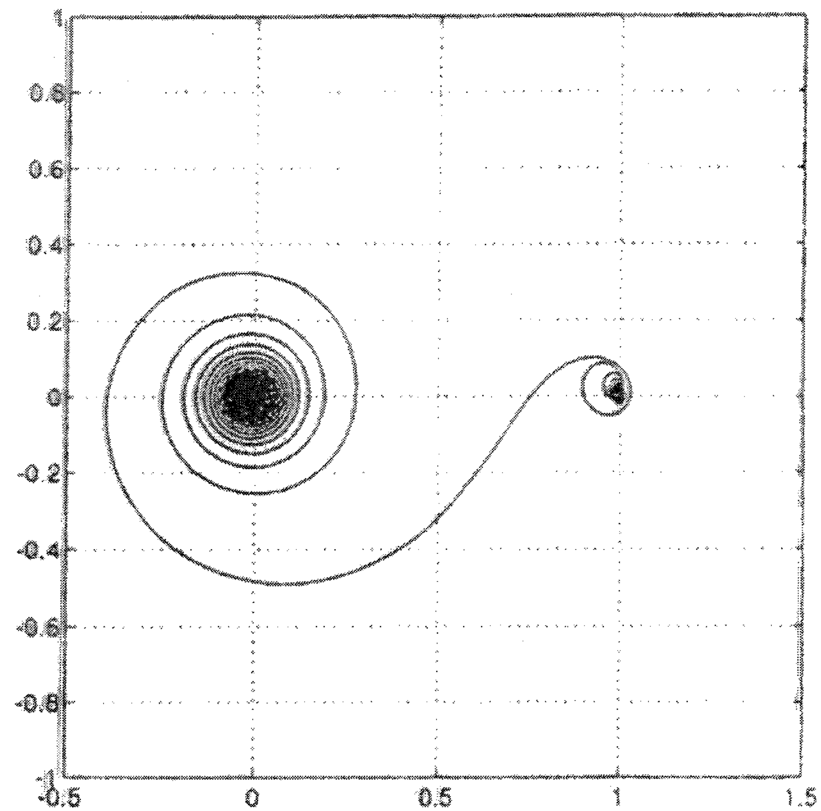
- New Approach
- Real World Model
- ΔV=3.838km/s
- Trip Time, 4-5 months

BELBRUNO AND MILLER: EARTH-TO-MOON TRANSFERS



Limited Power Engine

- Constant Thrust
- Uses Untested Technology
- Trip Time, 2 years



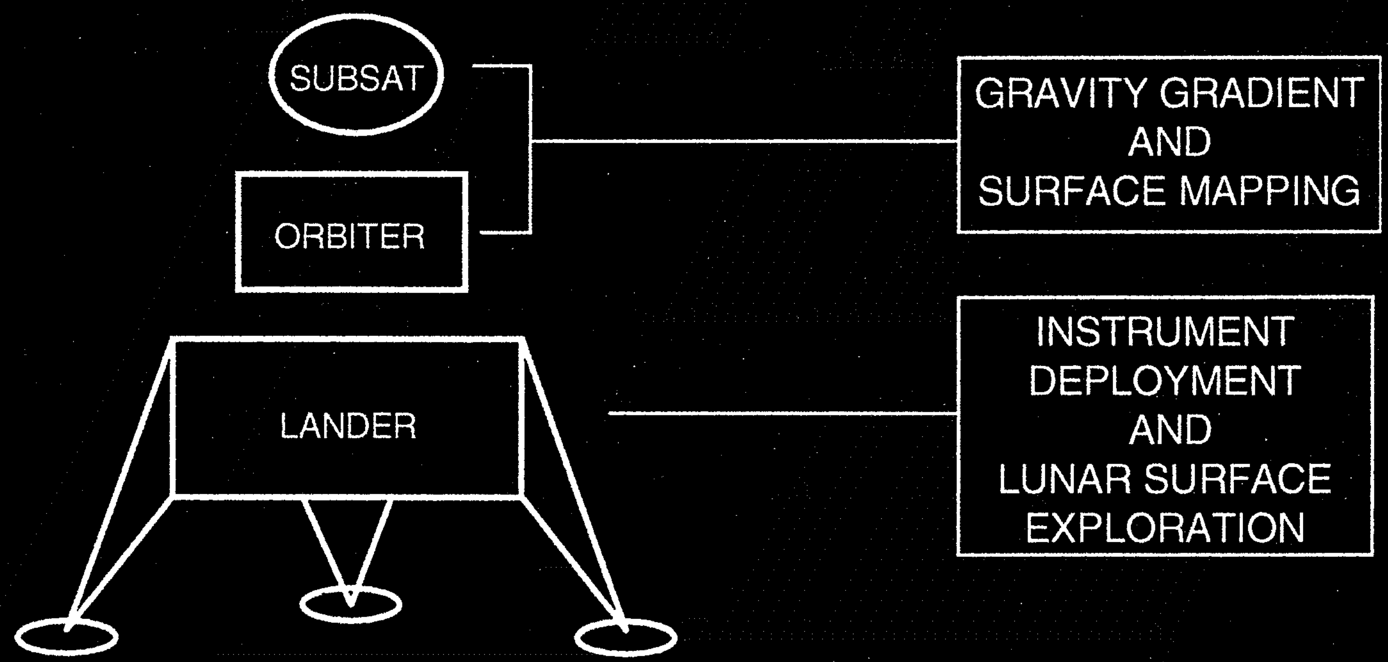
Summary

Type	Total ΔV	Trip Time
Hohmann	3.959 km/s	5 days
Bielliptic	4.148 km/s	4 months
WSB	3.838 km/s	4-5 months
Limited Power	Constant Thrust	2 years

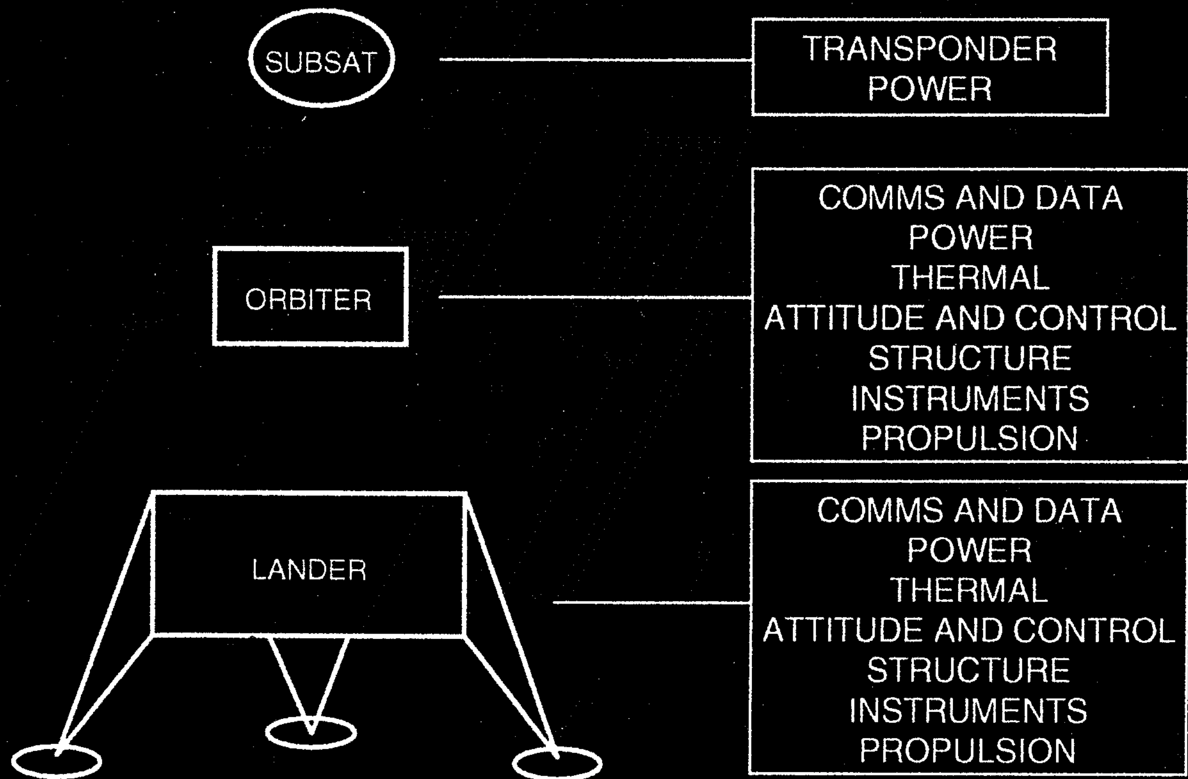
SPACECRAFT CONFIGURATION

- SYSTEM BASE LINE CONFIGURATION
- SUB-SYSTEM BASE LINE CONFIGURATION
- TRADE OFF ANALYSIS

SYSTEM BASE LINE CONFIGURATION

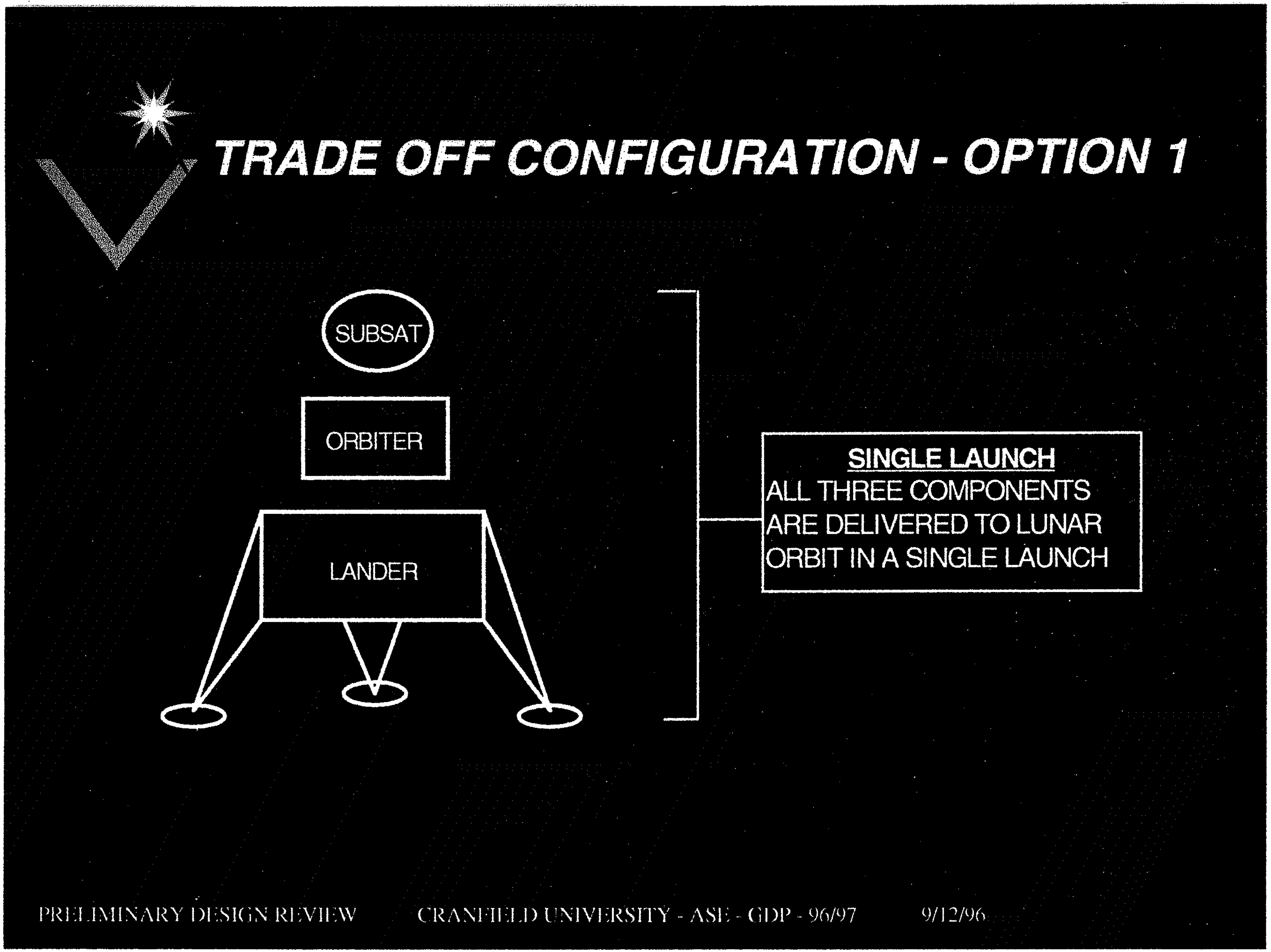


SUB-SYSTEM CONFIGURATION

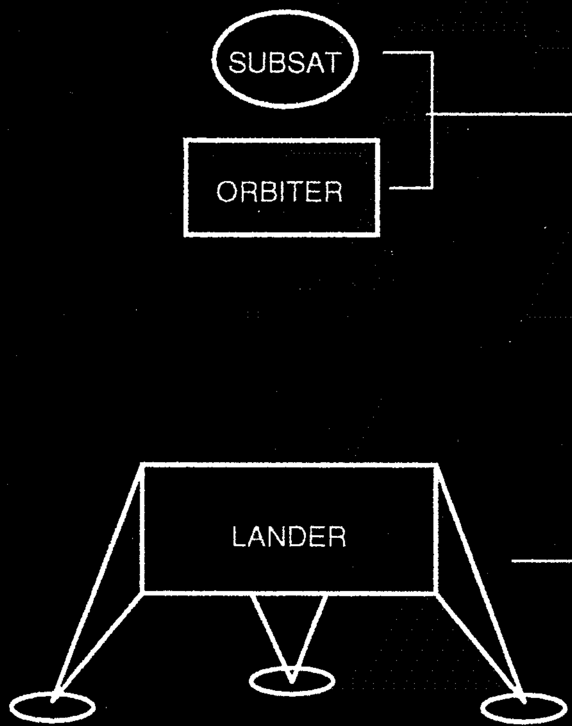


TRADE OFF ANALYSIS

- DEFINE TRADE OFF CONFIGURATIONS
- METHODOLOGY


TRADE OFF CONFIGURATION - OPTION 1
SUBSAT
ORBITER
LANDER
SINGLE LAUNCH
ALL THREE COMPONENTS ARE DELIVERED TO LUNAR ORBIT IN A SINGLE LAUNCH
PRELIMINARY DESIGN REVIEW
CRANFIELD UNIVERSITY - ASE - GDP - 96/97
9/12/96

TRADE OFF CONFIGURATION - OPTION 2



1ST LAUNCH

SUBSAT AND ORBITER ARE DELIVERED TO 100km LUNAR ORBIT BY TAURUS LAUNCH VEHICLE FOR GRAVITY AND SURFACE MAPPING.

(PERFORMANCE OF TAURUS TO BE FULLY ASCERTAINED FOR THIS TYPE OF MISSION PAYLOAD DELIVERY.)

2ND LAUNCH

LANDER DELIVERED TO LLO ORBIT BY SECOND LAUCH AFTER MAPPING DATA FOR LANDING SITE HAS BEEN ANALYSED.

TRADE OFF METHODOLOGY

- REVIEW TRADE OFF CONFIGURATIONS IN GENERAL
- IDENTIFY TRADE OFF PARAMETERS
- ASSIGN A SCORE FOR EACH CONFIGURATION FOR EACH PARAMETER
- APPLY AN APPROPIATE WEIGHTING TO EACH SCORE
- ADD THE SCORES TO DETERMINE THE RELATIVE TRADE OFF PERFORMANCE OF EACH OPTION

REVIEW OF TRADE OFF CONFIGURATIONS

PARAMETER	OPTION 1	OPTION 2
COST	- - - - - - - - - - -	Increase in cost of ~$20m for launch. 1st launch: Taurus; 2nd launch: Ariane ?
SCIENCE RETURN MAPPING	- - - - - - - - - - -	Reduced mapping capability (No CCD cameras).
SCIENCE RETURN SURFACE		Reduced capability of instruments on *Lander*, which work in conjunction with CCD cameras. Instruments on *Rover* not used to full capability.
SCIENCE RETURN CRATER	Not affected by options considered.	Not affected by options considered.
VERSATILITY	- - - - - - - - - - -	Last minute changes to *Lander*. Independent design of components. Public interest kept of *Lander*.
OPERATIONAL FACTORS	Dormant Lander to monitor – fuel requirements for orbit maintenance. High thermal protection – more power, degradation	Two launches and two transfers to the Moon.
RISK LAUNCH	1st launch failure, lose all equipment including critical Lander	1st launch failure doesn't cancel mission, lose min. equipment. Taurus Tested for lunar transfer. Two launches and transfers.
RISK MANOEUVRES	1st separation: 500 km 2nd separation: 100 km	One separation. Two lunar transfers.
RISK DESCENT	Reactivating of *Lander*. Orbit lowering	Less mapping data, on IR&UV CCD. Placed into LLO by launch.

TRADE OFF PARAMETERS

- **COST**
  - HOW MUCH IS THE MISSION LIKELY TO COST
- **SCIENCE RETURNS**
  - HOW MUCH OF THE IDEAL MISSION REQUIREMENTS CAN BE SATISFIED
- **VARIABILITY / OPERATION CONSIDERATIONS**
  - WHAT LEVEL OF VARIABILITY (MISSION ADAPTABILITY) CAN BE BUILT INTO THE MISSION AND SPACECRAFT DESIGN
  - LEVEL OF ASSOCIATED COMPLEXITY OF MISSION / OPERATIONS CONTROL
- **RISK**
  - LIKELY LEVEL OF RISK DURING MISSION PHASES

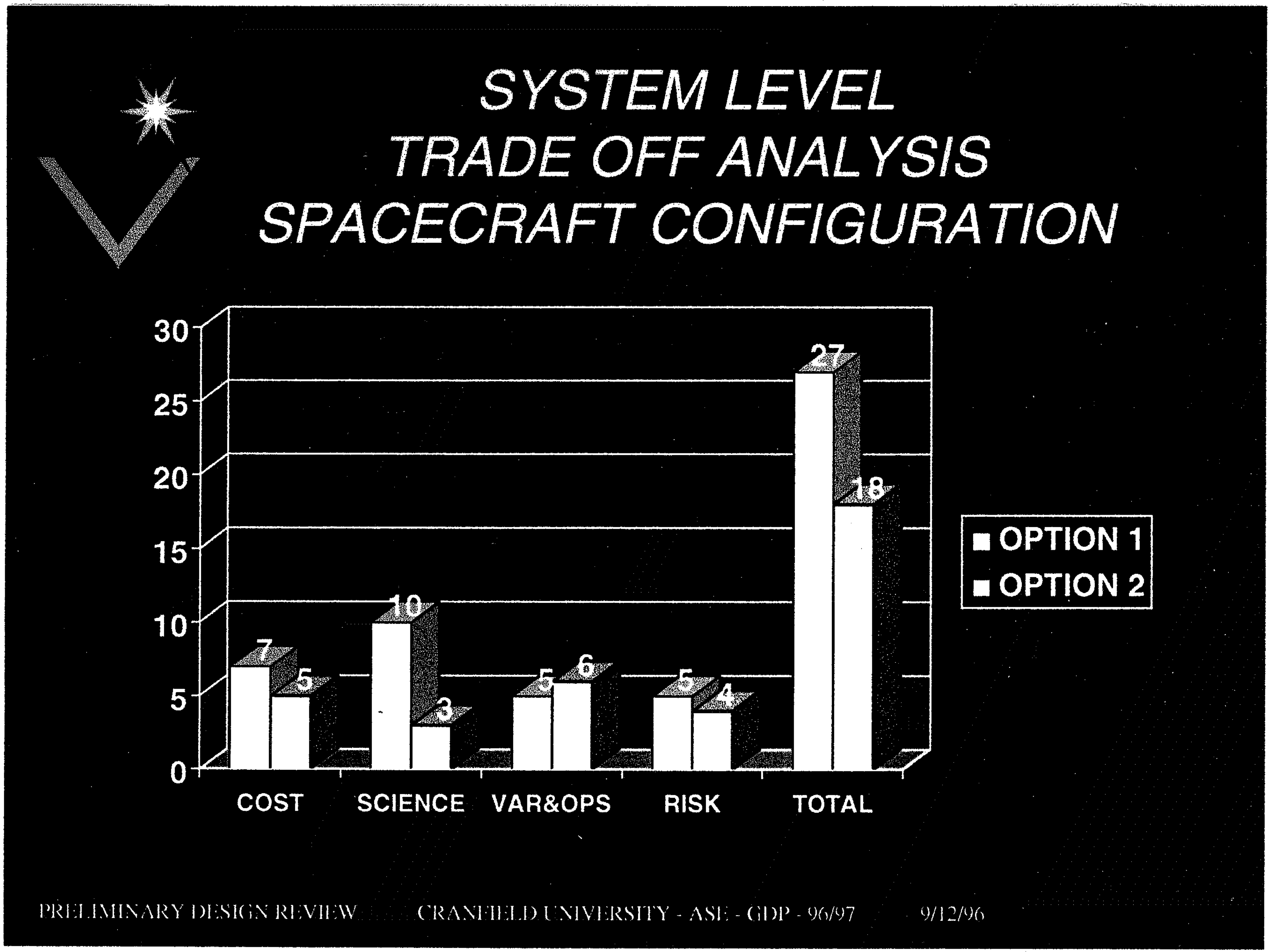
SYSTEM TRADE OFF ANALYSIS

	PARAMETER	OPTION 1 SCORE OUT OF 10	WEIGHTED RESULTS	WEIGHTED TOTAL	WEIGHTING FACTOR	OPTION 2 SCORE OUT OF 10	WEIGHTED RESULTS	WEIGHTED TOTAL
	COST	7	7	7	1	5	5	5
SCIENCE RETURNS	MAPPING	10	5		1/2	3	1.5	
	SURFACE	10	5	10	1/2	3	1.5	3
	CRATER	10	0			10	0	
VERSA AND OPS CONSIDERATIONS	VERSATILITY	6	1.8		3/10	10	3	
	OPERATIONAL FACTORS	10	3	4.8	3/10	9	2.7	5.7
RISK	LAUNCH	8	1.6		1/5	8	1.6	
	MANOEUVRES	8	1.6		1/5	6	1.2	
	DESCENT	8	1.6	4.8	1/5	6	1.2	4
	TOTAL			26.6				17.7

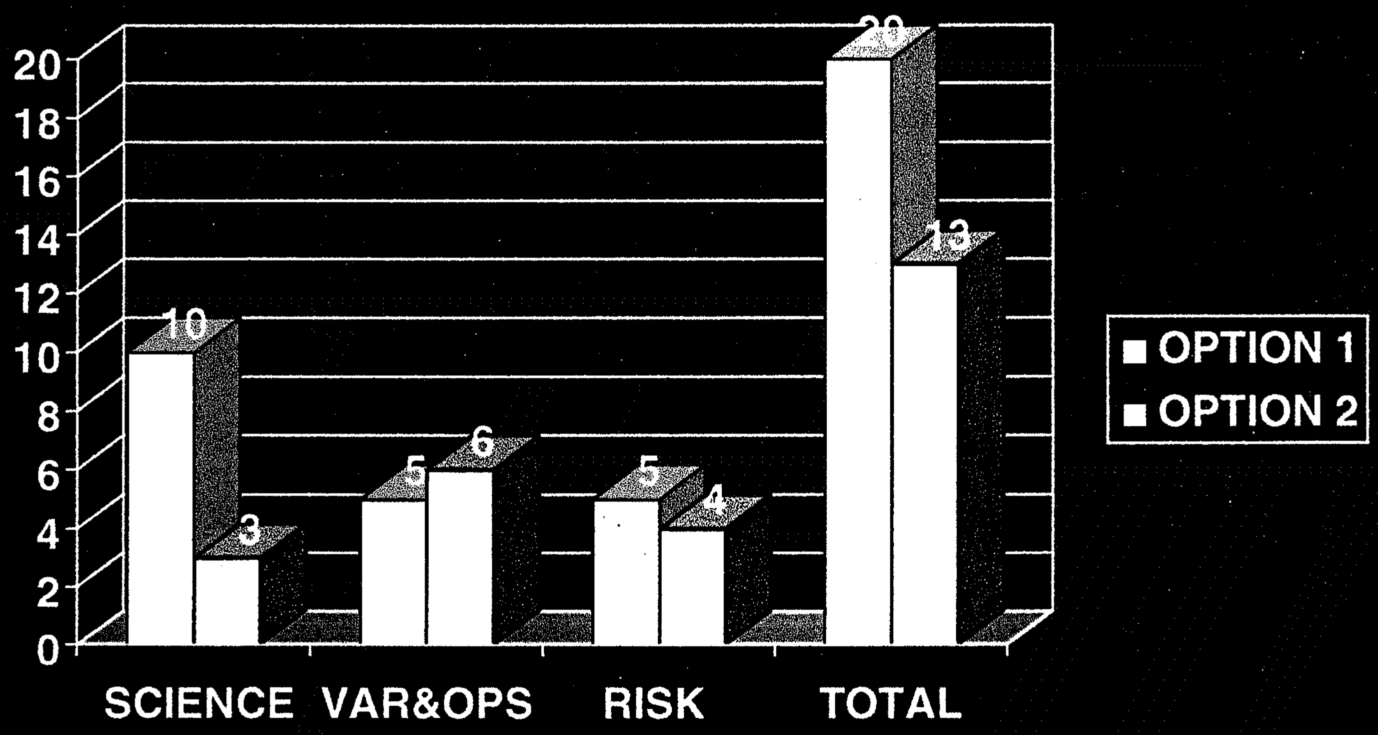
SUMMARY OF TRADE OFF ANALYSIS	OPTION 1	OPTION 2
COST	7	5
SCIENCE RETURNS	10	3
VERSATILITY& OPERATIONAL CONSIDERATIONS	5	6
RISK	5	4
TOTAL:	27	18

NOTE:
A HIGHER SCORE IMPLIES A MORE FAVOURABLE RATING.

PARAMETERS	WEIGHTING
COST LITTLE OR NO COMPROMISE	50%
SCIENCE RETURNS MAPPING SURFACE EXPLORATION CRATER EXPLORATION COMPROMISE POSSIBLE ON CERTAIN ASPECTS OF IDEAL SCIENCE REQUIREMENTS.	25%
VARIABILITY / OPERATION CONSIDERATIONS COMPROMISE POSSIBLE ON VARIABILITY OF MISSION AND SPACECRAFT DESIGN. THIS CAN INFLUENCE COST AND SCIENCE RETURNS.	15%
RISK LAUNCH MANOEUVRES DESCENT RISK IS INHERENT TO ALL SPACE MISSIONS. RISK ASSOCIATED WITH EVERY ASPECT OF MISSION IS DIFFICULT TO QUANTIFY EXACTLY.	10%

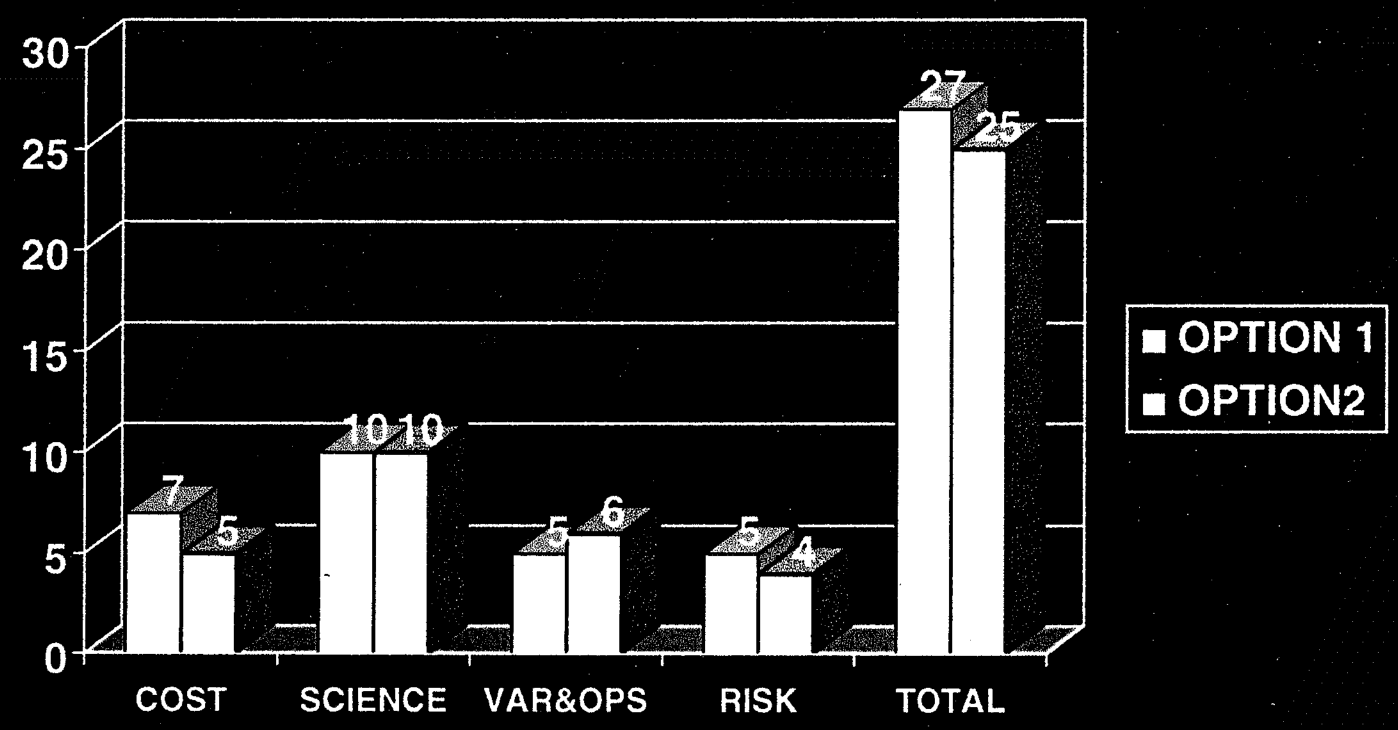

SYSTEM LEVEL
TRADE OFF ANALYSIS
SPACECRAFT CONFIGURATION
30
25
20
15
10
5
0
7
5
10
3
5
6
5
4
27
18
COST
SCIENCE
VAR&OPS
RISK
TOTAL
OPTION 1
OPTION 2
PRELIMINARY DESIGN REVIEW
CRANFIELD UNIVERSITY - ASE - GDP - 96/97
9/12/96

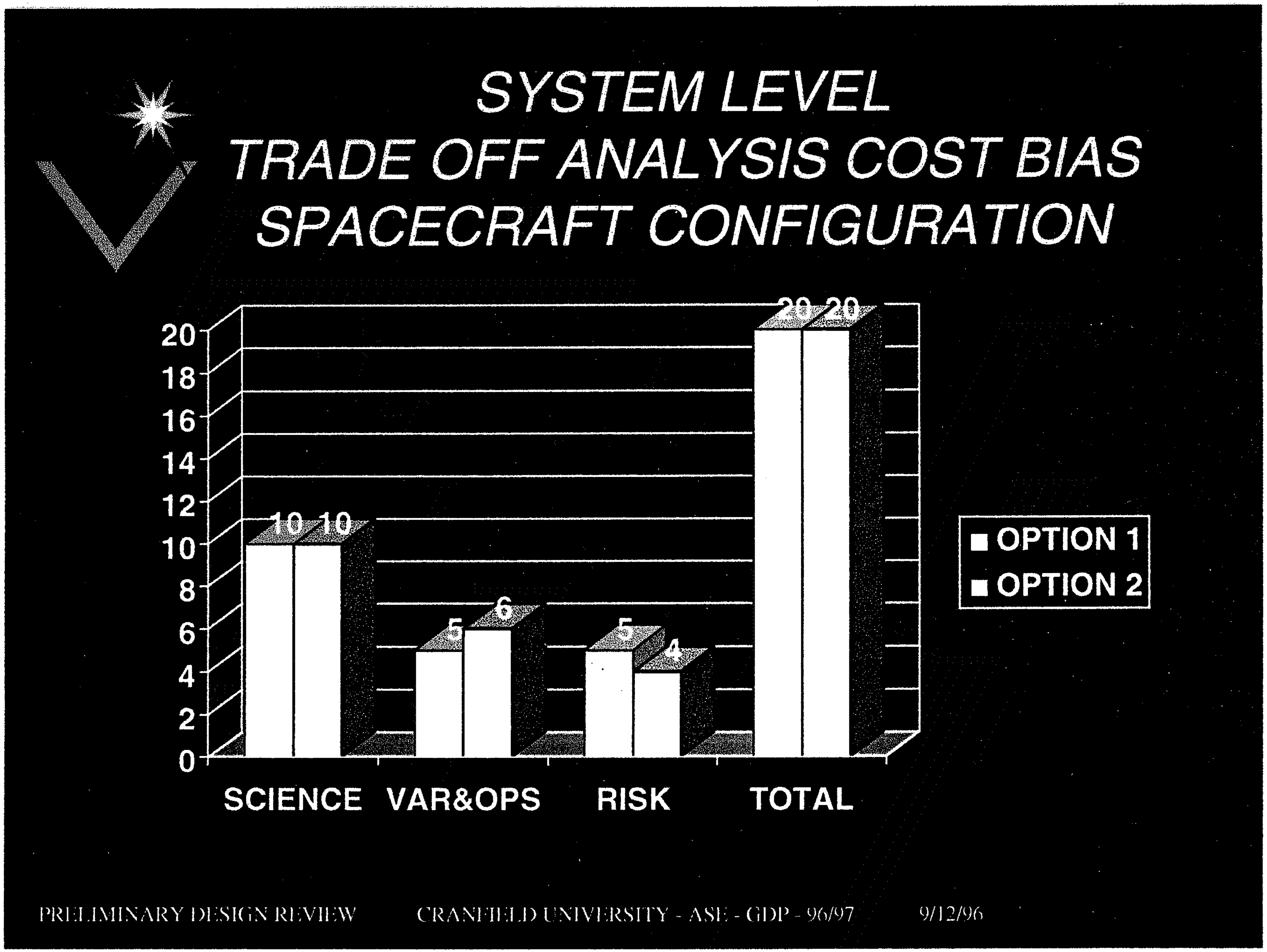
SYSTEM LEVEL
TRADE OFF ANALYSIS COST BIAS
SPACECRAFT CONFIGURATION



PRELIMINARY DESIGN REVIEW CRANFIELD UNIVERSITY - ASE - GDP - 96/97 9/12/96

SYSTEM LEVEL
TRADE OFF ANALYSIS
SPACECRAFT CONFIGURATION




SYSTEM LEVEL
TRADE OFF ANALYSIS COST BIAS
SPACECRAFT CONFIGURATION
20
18
16
14
12
10
8
6
4
2
0
10 10
5 6
5 4
20 20
SCIENCE
VAR&OPS
RISK
TOTAL
OPTION 1
OPTION 2
PRELIMINARY DESIGN REVIEW
CRANFIELD UNIVERSITY - ASE - GDP - 96/97
9/12/96

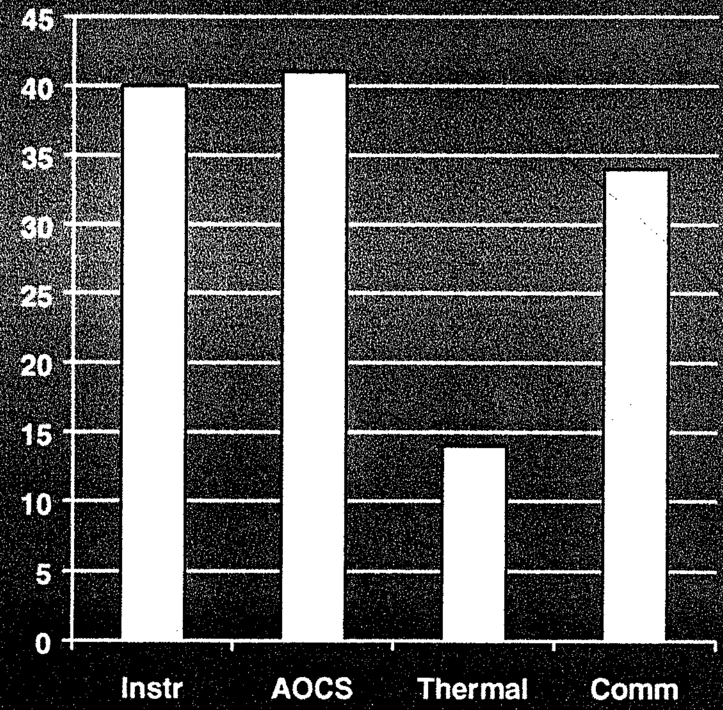
Preliminary Power Budget

5 Components to be power supplied:

- Orbiter
- Sub-Satellite
- Lander
- Rover
- Crater Probe

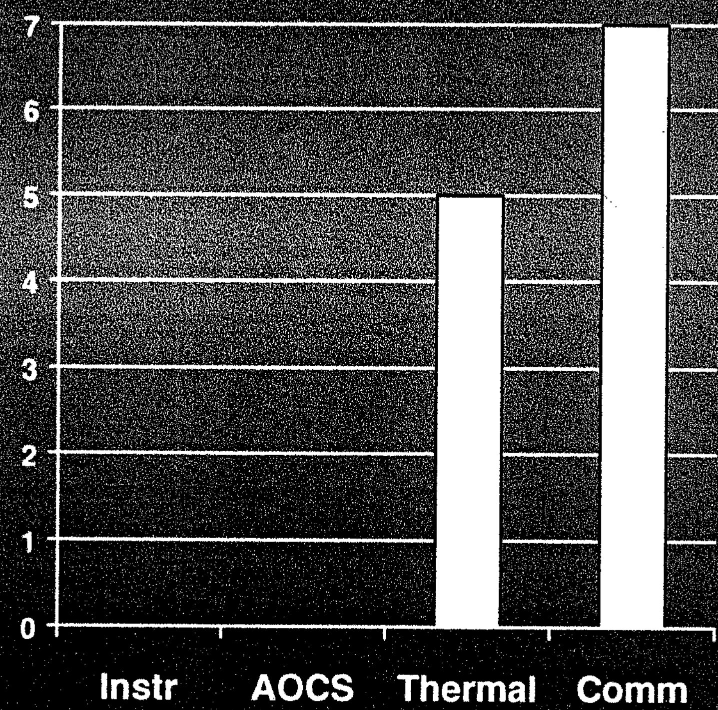
1/ Orbiter Power Budget

- 130W (continous demand) provided by Solar Arrays + Battery
- 2 hours period in lunar orbit (30% eclipse)
- EPS mass: around 10kg



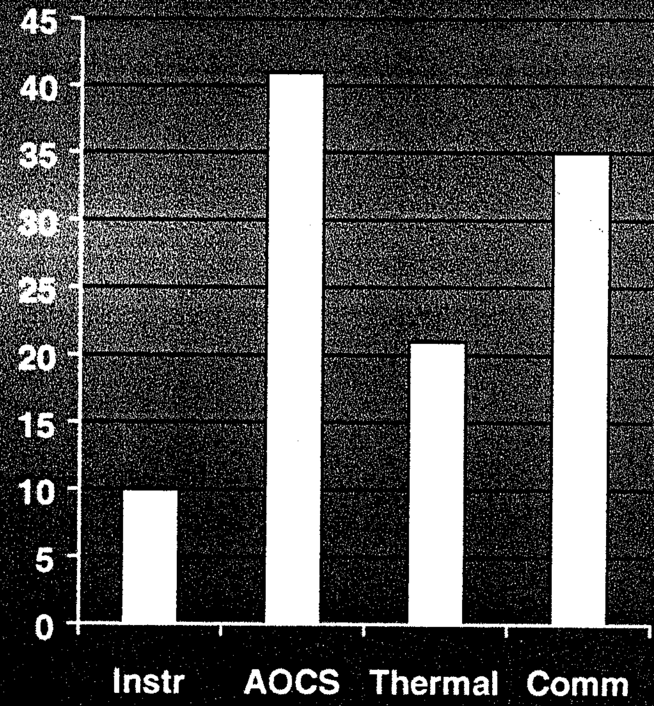
2/ Sub-satellite Power Budget

- 8W (continous demand) provided by Solar Arrays + Battery
- 2 hours period in lunar orbit (30% eclipse)
- EPS mass: around 550g



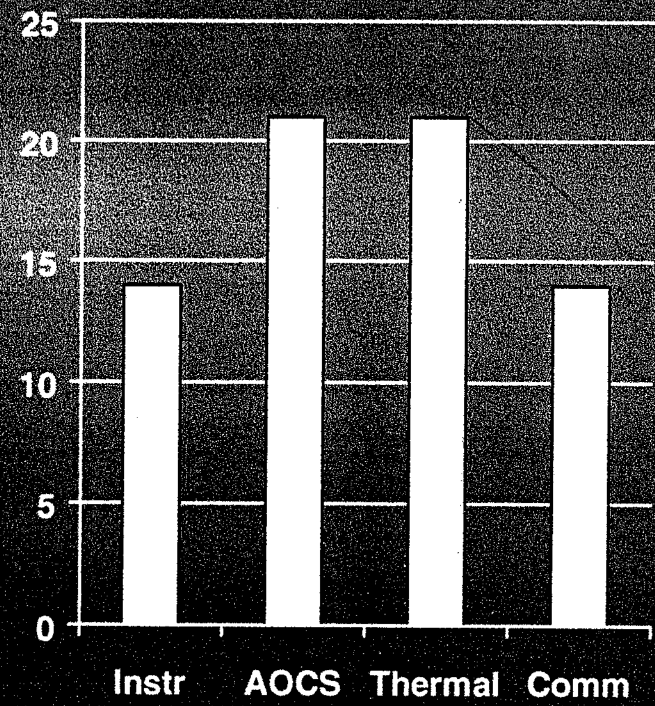
3/ Lander power Budget

- 100W (continous demand) provided by Solar Array + Battery
- Permanent light in landing area assumed
- Lander might provide power to the rover
- EPS mass around 6kg



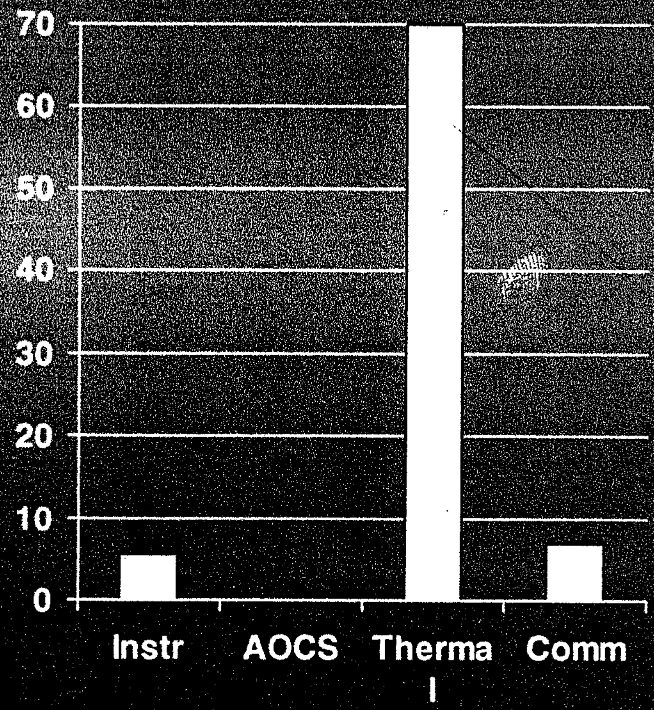
4/ Rover power Budget

- 70W (continous demand) provided by SA+Battery or Lander
- Permanent light in landing area assumed
- Instrumentation on while stationary



5/ Crater Probe Power Budget

- Around 80W continuous power demand without RTG or RHU
- Various power sources considered: RTG, Fuel Cells, Batteries...
- Mission duration requirements will determine the choice of the power source

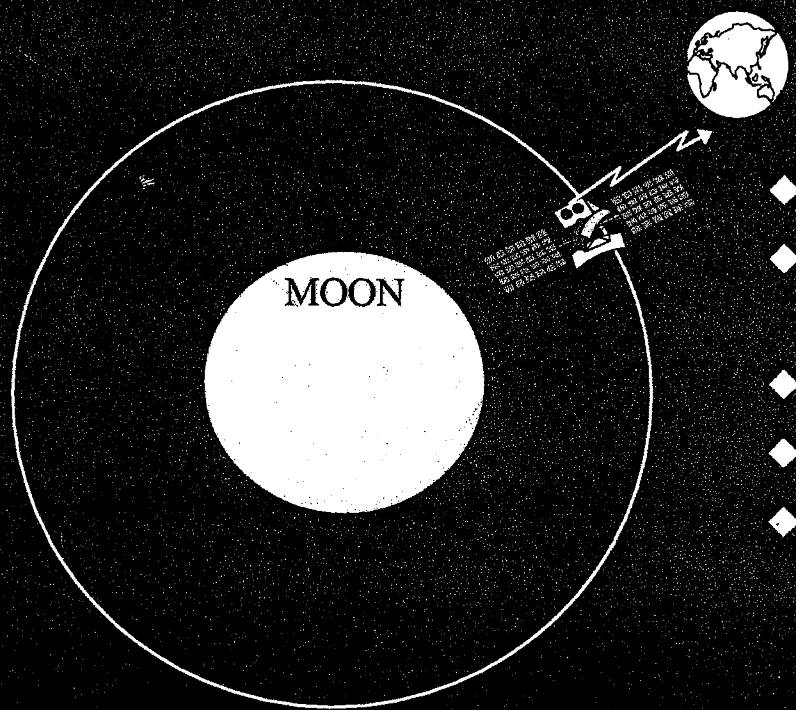


PRELIMINARY LINK BUDGET

COMMUNICATION LINKS

- Orbiter - Earth
- Lander - Earth
- Lander - Earth via Orbiter
- Rover - Lander
- Probe - Lander
- Probe - Orbiter

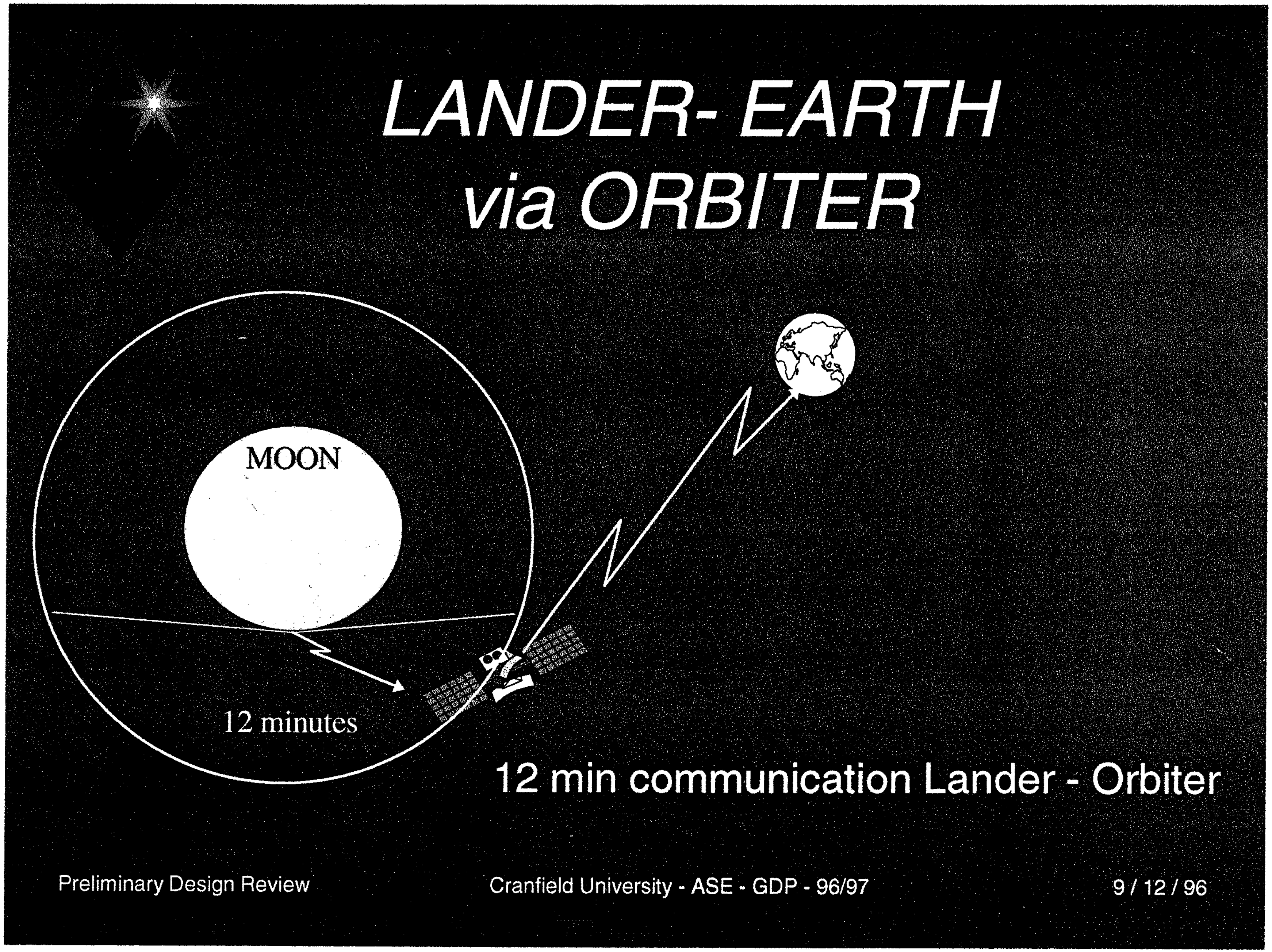
ORBITER- EARTH

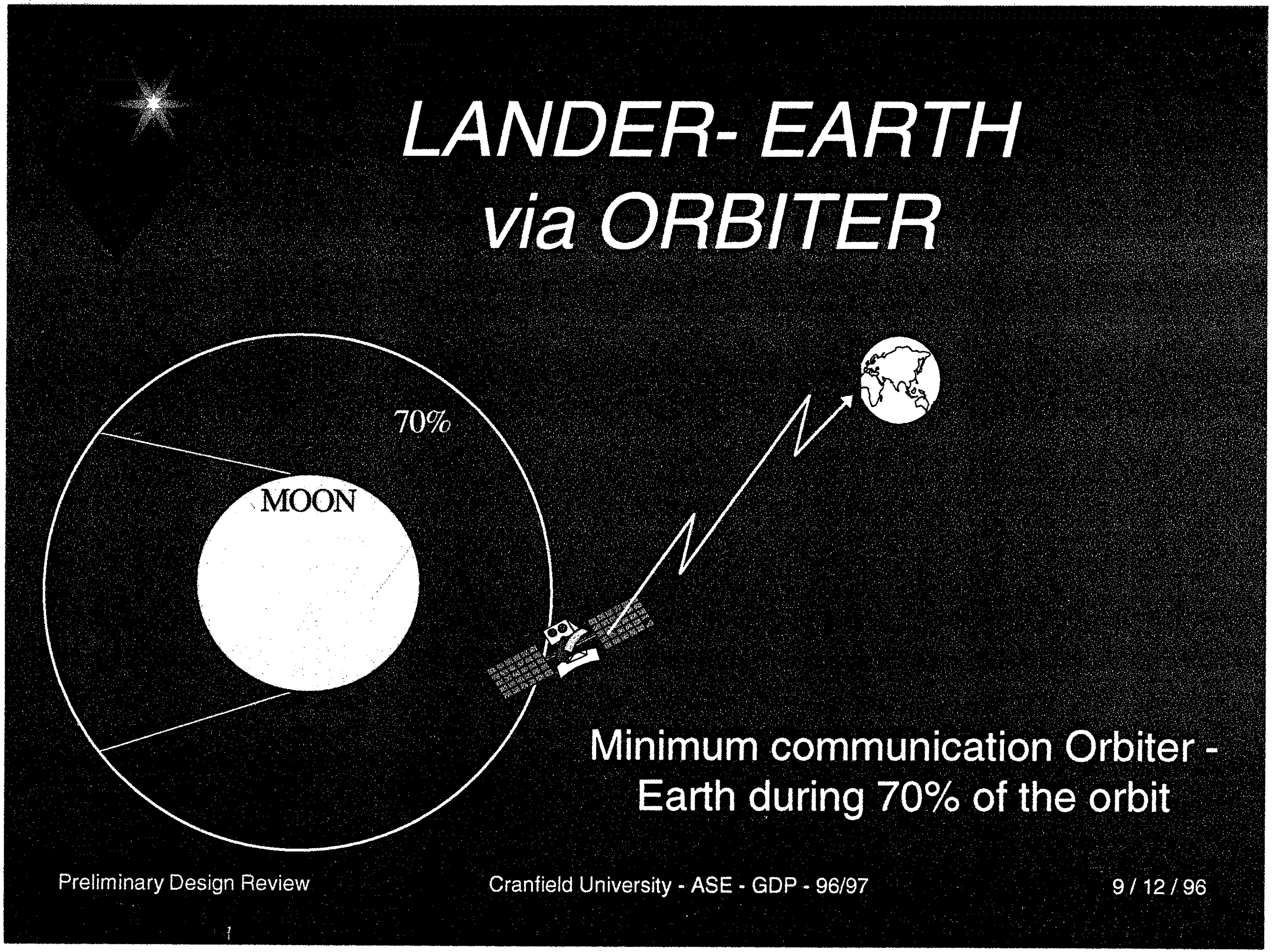


- Data Rate : 1.77235 Mbps
- Transmitter Power : 5 W
  (Receiver antenna diameter: 10m)
- Carrier Frequency : 2.255 GHz
- Antenna Beamwidth : 20 deg
- Antenna Diameter : 0.47 m

LANDER- EARTH via ORBITER

- Assume 14 days direct communication LANDER - EARTH
- Next 14 days use of ORBITER as relay
- Data rate have to be decreased


LANDER- EARTH
via ORBITER
MOON
12 minutes
12 min communication Lander - Orbiter
Preliminary Design Review
Cranfield University - ASE - GDP - 96/97
9 / 12 / 96


LANDER- EARTH
via ORBITER
70%
MOON
Minimum communication Orbiter - Earth during 70% of the orbit
Preliminary Design Review
Cranfield University - ASE - GDP - 96/97
9 / 12 / 96

ROVER - LANDER

- Rover in sight of the lander
- Use of Electromagnetic Waves or Optical Fibre
- Data Rate : 100093 bps

PROBE - LANDER

- Probe probably not in sight of the Lander
- Need to be linked to the Lander
- Low Data Rate : 5038 bps

ROVER - ORBITER

- Orbiter visible less than 12 min due to the sides of the crater
- Need of data storage
- Power required to send data

CRATER DESCENT

OPTIONS

1) MICRO SPACECRAFT
2)CABLE ASSISTED DESCENT
3) PROJECTILE
4) DROP FROM ORBIT
5) ABSEILING
6) INFLATABLE BALL METHOD

MICRO SPACECRAFT

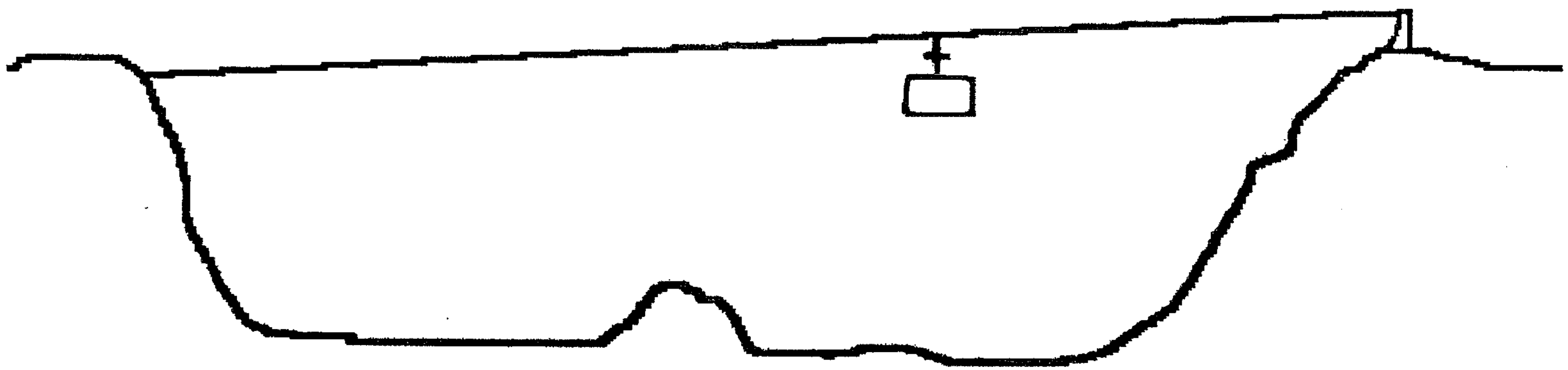
constant height flight

range(km)	upto 30

- 10 kg payload
- 21 kg spacecraft
- Ballistic trajectory

Cable Assisted Descent

- Kevlar cable
- Tensile strength 70,000kg/sq cm
- $^{1}/_{35}{}^{th}$ the weight of steel
- Simple penetrator anchor for far side of crater



DROP FROM ORBIT

- free fall penetrators
- possible need for deceleration
  - airbags
  - crumple zone
  - reverse trust rocket motor

PROJECTILE

- fired from lander
- capable of penetration
- need for turning projectile

PROBES

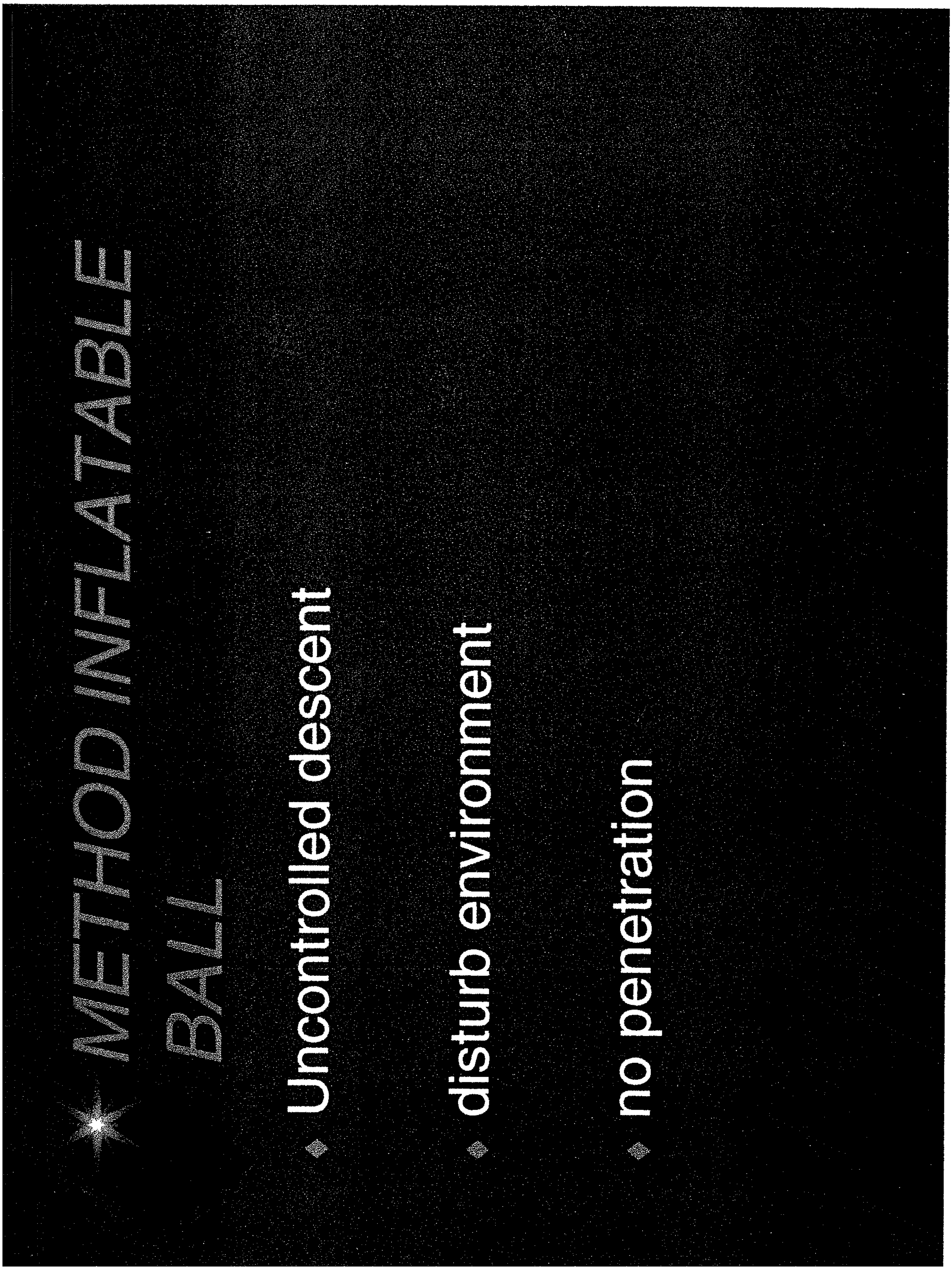
HARD LANDING PENETRATOR

max penetration depth	1-3m
penetrator mass	10-14kg
scientific package mass	1kg
overloads on impact	10,000g

(numbers based on LUNAR-A)

ABSEILING

- very slow (1m/hr)
- risk of land slides
- no penetration



METHOD INFLATABLE BALL
Uncontrolled descent
disturb environment
no penetration

Conclusion

Jason Maroothynaden

Conclusion

- Single spacecraft
- Spacecraft & precursor to the moon
- 2 scientific platforms
  - i. Orbiter; Geodesy sub. sat.
  - ii. Lander; Rover; Crater descent probes.

Conclusion

- Next stage of work to be done.
- European soft-landing on the Moon.
- European presence in Lunar South Pole.