431-SPEC-000112
Revision B
Effective Date: 4/11/2007
Expiration Date: 4/11/2007

Lunar Reconnaissance Orbiter Project

Technical Resource Allocations Specification

LRO GSFC CMO

April 11, 2007

RELEASED

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LRO CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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LUNAR RECONNAISSANCE ORBITER PROJECT

DOCUMENT CHANGE RECORD

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Rev Level	Description of Change	Approved By	Date Approved
Rev -	Released per 431-CCR-000141	D. Everett	05/31/2006
Rev A	Released per 431-CCR-000239	C. Tooley	10/31/2006
Rev B	Released per 451-CCR-000380	D. Everett	04/11/2007

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1.0 INTRODUCTION

1.1 PURPOSE

This document will be used to set and trace technical resources for the Lunar Reconnaissance Orbiter (LRO). This document will detail the process in which the technical resources are to be managed and controlled. It is expected this document will be a living document over the course of the mission.

The document will allocate mass, power, delta v, fuel, and data budgets.

1.2 APPLICABLE DOCUMENTS

The following documents (or latest revisions available) are applicable to the development and execution of this plan:

431-PLAN-000005	Lunar Reconnaissance Orbiter Systems Engineering Management Plan
431-PROC-000179	Lunar Reconnaissance Orbiter Configuration Management Procedure
431-RQMT-000004	Lunar Reconnaissance Orbiter Mission Requirements Document
431-SPEC-000008	Lunar Reconnaissance Orbiter Electrical System Specification
431-SPEC-0000091	Lunar Reconnaissance Orbiter Thermal Systems Specification
GSFC-STD-1000	GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems

2.0 TECHNICAL RESOURCE AND BUDGET TRACKING

2.1 DEFINITIONS

Figure 2-1 shows graphically the definitions that will be used in this document.

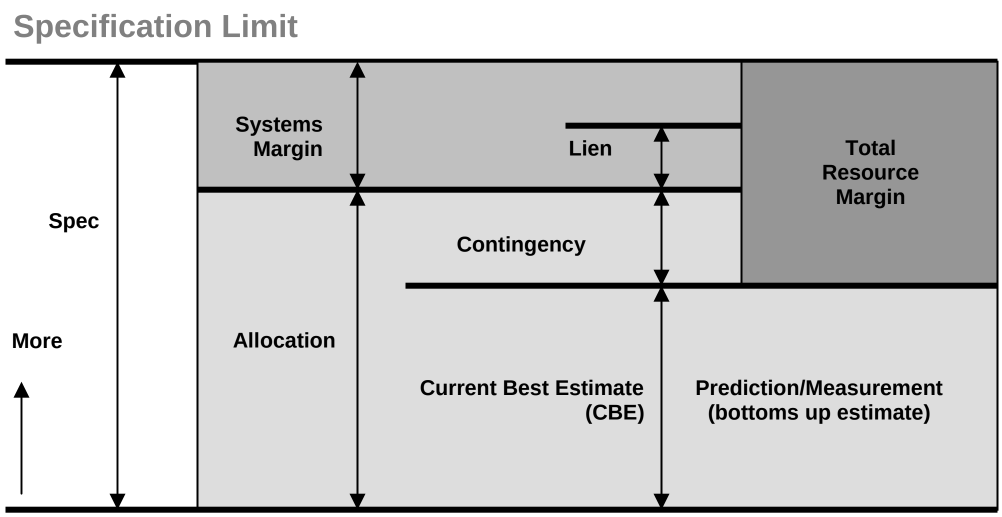

Figure 2-1. Resource Budget Nomenclature

2.1.1 Specification

Specification is the maximum amount of resources available.

2.1.2 Current Best Estimate

Current Best Estimate (CBE) is the current prediction or measurement of the resource. If it is a prediction, then it is a bottoms-up estimate.

2.1.3 Allocation

Allocation is the amount of resource assigned to a subsystem that the subsystem is allowed to manage. It equals the CBE plus contingency.

2.1.4 Contingency

Contingency is the reserve amount of resource under the control of the subsystem and is kept as part of the allocation.

2.1.5 System Margin

System Margin is the resource reserve managed at the system level. It is the difference between the overall resource specification and the assigned allocations.

2.1.6 Lien

Liens are a method of reserving Systems Margin by the Systems Engineering team while trade studies, procurements and allocation increase requests are being considered.

2.1.7 Total Resource Margin

Total Resource Margin is the sum of all margins above the CBE. The Total Resource Margin is the sum of the contingency plus the systems margin. Total Resource Margin will be used in all margin calculations to verify the Goddard Space Flight Center (GSFC) Standards are being met.

Margin shall be calculated as follows:

Margin (%) = (Specification–Current Best Estimate)/Current Best Estimate X 100

2.2 MARGIN PROGRESSION

The Systems Engineering team is responsible to identify the mission resources to be allocated and tracked at the project level, as well as to define acceptable resource margins and set up a margin management philosophy based on the various stages of the mission lifecycle phases.

Table 2-1 shows the LRO System Engineering resource allocation margin progression as the project development lifecycle proceeds through the various phases of mission development. The resource margins required decrease as the system development progresses to further levels of definition and maturity. The resource margins are taken from the GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GSFC-STD-1000).

For any given system or subsystem, the Total Resource Margin will be used in the resource margin requirement calculations from GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GSFC-STD-1000).

Table 2-1. LRO Resource Margin Progression

Total Margin Progression	Pre Phase A	Phase A	Phase B	Phase C	Phase D
Mass	30%	25%	20%	15%	0
Power (wrt EOL capacity)	30%	25%	15%	15%	10%*
Propellant	Margin detailed w/ Prop Budget				3 σ
Telemetry and Commands	25%	20%	15%	10%	0
RF Link	3dB	3dB	3dB	3dB	3dB

*At launch there shall be 10% predicted power margin for mission critical, cruise and safing operating modes as well as to accommodate in –flight operational uncertainties.

Table 2-2 shows the LRO System Engineering software margin approach.

Table 2-2. LRO Software Margin Progression

Mission Phase	FSW SRR	FSW PDR	FSW CDR	Ship/Flight
Method	Est.	Anal.	Anal./ Measured	Measured
Average CPU	50%	50%	40%	30%
CPU Deadlines	50%	50%	40%	30%
PROM	50%	30%	20%	0
EEPROM	50%	50%	40%	30%
RAM	50%	50%	40%	30%
1553 Bus	30%	25%	15%	10%
UART/ Serial I/F	50%	50%	40%	30%

Per the Systems Engineering Management Plan (431-PLAN-000005) the technical resources should be in draft form by System Requirements Review (SRR). Therefore, the initial allocations set in this document will be with the margins from Phase A in Table 2-1. At the Preliminary Design Review (PDR), the margin progression will be at the levels for Phase B. At the Critical Design Review (CDR), the margin progression will be the levels for Phase C. At launch, the margins will be at the levels specified for Phase D.

2.3 ALLOCATION APPROACH

2.3.1 Overall Approach

Allocations, per the definition in Section 2.1, consist of the CBE and the contingency. CBEs are calculated by each subsystem and presented, with any technical detail, to the Spacecraft Systems Lead. Depending upon the amount of design maturity in the subsystem, a Design Maturity is designated to the subsystem or to the components within the subsystem. Depending upon the level of Design Maturity, a percent contingency is assigned to the resource and a resource value is calculated. At the Spacecraft Systems Lead's discretion, some or all of that contingency resource value is allocated to the subsystem. The remaining contingency resource value is maintained as System Margin by the Spacecraft Systems Lead. The sum of the System Margin plus the Subsystem Contingency is used to calculate the overall margin used to meet the progression requirements from Section 2.2.

2.3.1.1 Current Best Estimate

CBEs are estimated or calculated by the subsystems. Estimates are to be provided to the Spacecraft Systems Lead with any assumptions that were made. CBEs range from guesses based on engineering judgment to tested values from flight units. As the design matures, both the fidelity and accuracy of the estimate will increase. The assumptions and calculations behind the CBEs are critical to an effective management of resources.

The assumptions and calculations will be documented in the Master Equipment List (MEL). The MEL is a tracking tool used by the Spacecraft Systems Lead. The MEL will track CBEs against allocations from concept to launch. Monthly updates are posted to the LRO Project internal website.

2.3.1.2 Design Maturity

As the maturity of the system architecture increases, the precision of the resource estimates will improve with the method of estimating the required resources. Table 2-6 and Table 2-8 illustrate the LRO margin factors that will be applied to the system elements as they progress through the various levels of development maturity. These factors will be applied against their appropriate estimates to determine a contingency resource value. The Spacecraft Systems Lead will allocate that resource value between the subsystem contingency and system margin. If the CBE is deemed to be conservative, the Spacecraft Systems Lead may keep a portion of the contingency resource value at the system level, reducing the subsystem allocation.

Table 2-3. LRO Mass Design Maturity Factors

Mass Design Maturity	Contingency Allocation %
Calculations from sketches/schematics	25
Calculations from preliminary layout	20
Calculations from detailed layout/Major modified unit	15
Calculation from pre-released drawing/Moderate modified unit	10
Calculation from released drawing/Minimum modified unit	5
Actual weight for similar flight hardware/Engineering model	3
Actual weight for flight hardware	0.5

Table 2-4. LRO Power Design Maturity Factors

Power Design Maturity	Contingency Allocation %
New units containing new technologies or Thermal Control System (TCS) components	20-25
New units based on existing technology	15-20
Major modifications to existing units	10-15
Minor modifications to existing units/New units with engineering models	5-10
Off the shelf, flight qualified units	3-5

2.3.1.3 System Margin

The Project or Spacecraft Systems Lead maintains the System Margin. The margin would be any resources remaining after the CBE as calculated and the assigned contingency allocations are subtracted from the resource specification. At the system level, specifications will be generated to determine the amount of available resources exists. For mass, it would be the maximum throw weight of the launch vehicle.

The System Margin will be distributed, as appropriate, over the design phase of the mission. Distribution of the margin to Subsystem Allocations will require a configuration change request (CCR) to this document per the Lunar Reconnaissance Orbiter Configuration Management Procedure (431-PROC-000179). The CCR will require formal documentation as to the reason the allocations are to be changed. Most often, trade studies will be requested to show adequate efforts were made to maintain the allocation. Some changes in allocation will be accepted as a trade against cost or schedule savings.

2.3.1.4 Liens

Liens will be levied and maintained by the LRO Systems Engineering team. The LRO SE team will track all outstanding liens as a subset of the Systems Margins. Liens will be granted for numerous reasons. Primary reasons they may be granted are to document ongoing trade studies in which results may not be known in an adequate amount of time to close a CCR

2.3.1.5 Total Resource Margin

System Margin will be combined with the subsystem contingency to determine the overall resource margin. The overall resource margin will be used to show adequate design margin as required by the GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GSFC-STD-1000).

2.3.2 <u>Initial Allocations</u>

2.3.2.1 Spacecraft

Initial specifications for the space segment were derived for the following resources.

2.3.2.1.1 Mass

The mission traded different designs regarding a transfer to lunar orbit. The project examined various direct lunar insertion trajectories and phasing loops. The project also traded mono-propellant verses bi-propellant verses hybrid propellant systems.

Given a Level 1 requirement of using an intermediate class launch vehicle, the best solution was for a mono-propellant system on a direct lunar insertion trajectory. Further analysis has yielded a maximum throw mass for the launch vehicle of 1480 kilograms (kgs). This throw mass set the initial mass specification.

The project also looked at adding a Solid Rocket Motor due to concerns with the spacecraft's Nutation Time Constant (NTC). The overall mass allocation did not change since the launch vehicle capability remained the same.

The project has now settled on using an Evolved expendable launch vehicle (EELV) verses an intermediate class launch vehicle (Delta-IV or Altas-5) per Headquarters' (HQ) direction. This has increased the throw mass capability from 1480 kgs to 1846.5 kgs. The new specification limit for the Orbiter is 1846.5 kgs.

Selection of the Atlas 5 launch vehicle and further detailed analysis of our Delta V budget has resulted in an updated throw mass capability of the orbiter. The new capability was increased to 1944.4 kg. This assumes 895 kg of propellant and 3.4 kg of pressurant. This results in 1044 kg of orbiter dry mass.

2.3.2.2 Subsystems

At approximately the time of the Instrument Accommodations Review, subsystem allocations were set against the appropriate resource specification. The timing was chosen to freeze allocations and show adequate Overall Margin at the start of subsystem and instrument PDRs.

The MEL contains CBE for the subsystem and an assigned Design Maturity rating. Spacecraft Systems appropriated the resource contingency value, as appropriate, to maintain adequate Overall Margin per the GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GSFC-STD-1000). The contingency value assigned to each subsystem is also shown in the MEL.

2.3.2.3 Instruments

Initial instrument allocations were set from the instrument proposals. Most proposals included contingency. For the initial allocations, the CBE and contingency were accepted as proposed. For those instruments which proposed less than 15% contingency, the instrument contingency was increased to 15% and the allocation was set.

It is important to track any variations to the originally proposed resources. It was understood that the spacecraft could impose design changes on the instruments. It is in both party's interests to track resource growth against the true cause of it. For spacecraft induced changes like requiring different electrical interfaces, it is important to trade the impacts with regard to all resources (cost, mass, power). For allocation growth due to self-imposed design changes, it is important for the Spacecraft to have insight into major changes and the trades that decided those changes. Design heritage and maturity was a criterion for instrument selection and deviations from the proposed design should be scrutinized.

At the release of this document, both the instruments and the spacecraft have been more defined. Mass and power estimates have become more defined. Those current estimates are captured here. Appendix D captures the resource history.

2.3.3 Reallocations

Changes to the allocations will be handled per the Lunar Reconnaissance Orbiter Configuration Management Procedure (431-PROC-000179). The reallocation will be addressed as part of a Configuration Control Board (CCB).

To expedite the process, it is required that any subsystem requesting a reallocation provide technical documentation supporting the request. Engineering discipline should be applied to show a good faith effort to remain within the allocation. The documentation can include results from trades of mass against cost and schedule. There should also be detail in the new mass estimate. Engineering rigor should be applied in determining the new resource allocation.

3.0 MASS ALLOCATION

The overall Orbiter mass allocation is traced from the Lunar Reconnaissance Orbiter Mission Requirements Document (431-RQMT-000004, requirement MRD-1). The Consumables Allocation is derived from Table 5-1, Delta V Allocation. Section 5.0 derives the Delta V allocation and the requisite fuel to perform those Delta V maneuvers. Assuming full fuel tanks, a maximum throw mass was derived. Subtracting the fuel mass from the throw mass yields the maximum allowable dry mass. Those allocations are set below.

Table 3-1. Spacecraft Mass Allocation - Wet

Subsystem	Specification (kg)	Comments
Allocation from LV	**2000.0**	From LV ICD
Allowable Mass for dV	**1944.4**	Derived from max Delta V
Max Dry Mass	**1046.0**	Max Allowable mass less consumables
Consumables	**898.4**	Propellant and Pressurant

The wet mass consumable allocation is derived from the Table 5-1 Delta V Allocation budget.

Table 3-2. Spacecraft Wet Mass Allocation - Consumables

Subsystem	Specification (kg)	Comments
Consumables	**898.4**	
Hydrazine	**895.0**	Derived from Delta V Budget, includes 3 σ
Pressurant	**3.4**	

The spacecraft dry mass allocation is derived from the launch vehicle “throw mass” less the Consumables Allocation from Table 3-2. Any difference between the Max Dry Mass Allocation from Table 3-1 and the Total Dry Mass from Table 3-3 will be kept as System Margin. The Orbiter Systems team will keep that mass and will distribute it later as justified.

Table 3-3. Spacecraft Dry Mass Allocation

	ALLOCATION	CURRENT BEST ESTIMATE	CONTINGENCY ASSIGNED TO SUBSYSTEM	CBE + DESIGN MATURITY	DESIGN MATURITY	DM
S/C Bus (Dry Mass)	**918.97**	**856.54**	**7.3%**	**944.48**	**10.3%**	**3.7**
ACS	**63.8**	61.1	4.4%	63.8	4.2%	2.7
Battery	**37.0**	35.2	5.1%	38.7	9.1%	3.0
C&DH	**27.2**	24.9	9.2%	27.2	8.4%	3.8
Harness	**85.6**	71.7	19.5%	88.6	19.1%	4.9
High Gain Assy.	**55.9**	50.1	11.5%	53.2	5.9%	3.2
Ka Comm	**8.5**	7.7	10.0%	8.5	9.1%	4.0
PDE	**11.0**	9.7	13.0%	10.4	6.2%	3.3
Propulsion (Dry Mass)	**148.0**	140.6	5.3%	148.0	5.0%	2.6
Power (PSE)	**17.0**	17.0	0.4%	17.5	2.9%	2.0
S/C Bus Structure	**260.0**	244.3	6.4%	281.0	13.0%	5.0
S Comm	**11.5**	9.2	25.1%	10.0	8.5%	3.8
Solar Array Assy.	**105.1**	101.9	3.1%	107.9	5.5%	3.1
Laser Ranging	**0.5**	0.5	8.0%	0.5	7.4%	3.6
Thermal	**88.0**	82.7	6.4%	89.2	7.3%	3.1

Instrument	**99.84**	**89.14**	**12.0%**	**96.88**	**8.7%**	**3.6**
CRaTER	**6.4**	5.3	20.8%	5.6	4.8%	3.0
Diviner	**13.0**	12.1	7.3%	12.8	5.2%	2.7
LAMP	**5.3**	4.8	10.4%	4.9	2.9%	2.0
LEND	**26.0**	26.0	0.0%	26.3	9.1%	4.0
LOLA	**15.3**	13.1	16.5%	14.0	6.2%	3.3
LROC	**19.9**	17.1	16.1%	18.0	4.8%	3.0
Mini RF	**16.0**	12.7	26.0%	15.2	16.7%	6.0

4.0 POWER ALLOCATION

Power consumption is highly mode dependent and can vary with orbital location, bus voltage, and other spacecraft component configurations. Power allocations are to be calculated against a nominal, fully operational orbit average scenario unless otherwise noted.

In assessing power allocations for the mission, Systems assessed the lowest margin with respect to energy balance for nominal operations (i.e., the highest power consumption during the lowest power generation).

The highest predicted power consumption during nominal operations occurs during the Measurement Operations Phase when both S-Band and Ka-Band contacts occur in the same orbit. Other phases, like the Cruise Phase, Delta V/ Delta M Operations, or Sun Acquisition, are not drawing maximum power. These phases are being used to size the power subsystem, not drive the allocations.

The lowest power generation during this operations phase occurs during maximum lunar occultation (at Beta 0).

The maximum lunar eclipse is addressed in the Lunar Reconnaissance Orbiter Mission Requirements Document (431-RQMT-000004). MRD-19 requires the spacecraft to be able to handle an eclipse of 160 minutes. The baseline operations for this mode are to hibernate the Orbiter during the lunar eclipse.

Power allocations are split into two categories: Instruments and the Spacecraft Bus. Their allocations are presented in Tables 4-1 and 4-2, respectively. The tables identify the subsystem rack-up of allocated power (dark gray rows). Every service allocated is also listed in light gray rows. Further breakdown of a service is shown in white rows. The allocations are broken down to this level to assist with tracking the power dissipations for the thermal design. It is important to track power expended at the box level. Since some services are split amongst multiple boxes, this document will track allocations down to that level. When box level interface control documents (ICDs) are released, allocations to this level may be transferred and tracked in the ICDs.

Each allocated service (light gray row) lists the de-rated service size in amps (1,2,5,10, or 15) and whether the services is switched (SW) or un-switched (US). The Orbit average power allocation is listed followed by the maximum allowable duty cycle per orbit. The final eight columns detail the power allocations per mission phase. From this, it can be inferred what subsystems and components are powered during each phase.

That Orbit Average Power is the maximum average power allowable for the S+Ka Band Orbit. The orbit average is defined as the power expended over one orbit (113 minute period). The maximum power allowable before activating the current limit is defined in the Lunar Reconnaissance Orbiter Electrical Systems Specification (431-SPEC-000008). This sets the peak power limit for each service. Care must be taken to not to exceed this peak limit across the entire voltage range expected. Peaks, integrated over time, must not exceed the orbit average allocation in this document

The power system is sized to be able to fully recharge the battery each orbit for the max lunar occultation (48 minutes) using End of Life (EOL) properties. For the LRO power subsystem, the maximum orbit average power allowable is 823 watts (W). The allocations were set against this limit for the S+Ka Band Orbit. Since not all components are active during this orbit, simply summing the allocation tables will exceed the 823W. The proper breakdown is tracked in the LRO Master Equipment List, and Total Resource Margins are tracked there. This document is a living document that is updated monthly, at a minimum. It resides on the LRO Project internal website.

For components (except heaters) not active during the S+Ka Band Orbit, allocations were set following the Design Maturity Process described in Section 2.3.1.2.

Heater allocations were set at the Beta 0 case for the S+Ka Band Orbit. However, the Beta 0 case is considered the Hot Case for thermal. Allocations were still set at Beta 0 since this is the lowest spacecraft power generation case. As the orbit progresses to Beta 90, the heater power will increase. At the same time, power generation capability will increase as well. For the current state of design maturity at SRR, the Beta 0 case was selected as the limiting case. The Beta 90 case and any other inflections points in an energy balance curve will be monitored. As the design and analysis matures, Beta 0 will remain the driving allocation case, but Total Resource Margin may be calculated against a different Beta case.

The Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091) breaks down the heater allocations further. The Thermal Lead Engineer will be responsible for the total thermal management of the spacecraft and will allocate and manage the thermal control system to meet the power allocation requirements. The overall heater allocations are specified in this section.

4.1 INSTRUMENT POWER ALLOCATIONS

Table 4-1. Instrument Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manueve
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)
Instrument	CRaTER	1	113	9.00							6.70	6.70	6.70	6.70	9.00	6.70
Instrument	Diviner Instrument	2	113	13.20										12.00	13.20	12.00
Instrument	Diviner Remote Electronics Box	2	113	28.90										23.30	28.90	23.30
Instrument	LAMP	2	113	2.40										2.20	2.40	2.20
		2	113	2.40										2.20	2.40	2.20
Instrument	LEND	1	113	13.00							13.00	13.00	13.00	13.00	13.00	13.00
Instrument	LOLA MEB		113	20.40										16.70	20.40	16.70
Instrument	LOLA MOB OTA		113	19.30										16.80	19.30	16.80
Instrument	**LOLA SERVICE TOTAL**	2	113	**39.60**												
Instrument	LROC (SCS)	1	113	6.00										4.80	6.00	4.80
Instrument	LROC (NAC-1)	1	113	10.00										6.20	10.00	6.20
			0											0.00	0.00	0.00
Instrument	LROC (NAC-2)	1	113	10.00										6.20	10.00	6.20
			0											0.00	0.00	0.00
Instrument	LROC (WAC)	1	113	4.00										2.30	4.00	2.30
			0											0.00	0.00	0.00
Instrument	**LROC DECON SERVICE TOTAL**	5	0	**98.00**												
Instrument	Mini RF (Main)	2	113/8	4.00	← ▲35.1									2.52	4.00	2.52
Instrument	Mini RF (PA)	5	8	7.20	←▼3									4.59	7.20	4.59
INSTRUMENT	**TOTAL (NO HEATERS)**			**149.80**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**19.70**	**19.70**	**19.70**	**119.51**	**149.80**	**119.51**
INSTRUMENT	**HEATER TOTAL**				**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

4.2 SPACECRAFT BUS POWER ALLOCATIONS

Table 4-2. RF Communications Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4.3
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lunar
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Eclipse
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Power
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Avg (W)
					0.00	0.00	0.00	0.00	0.00	0.00	19.70	19.70	19.70	119.51	149.80	119.51	0.00
Comm	TT&C XPDR	2	58	19.00			32.00	32.00	16.42	16.42	16.42	16.42	16.42	16.42	19.00	16.42	
		2	113	12.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	12.00	10.00	10.00
Comm	Modulator	2	58	17.70								30.00	15.40		17.70		
Comm	Transmitter		58	51.00								86.00	44.14		51.00		
Comm	EPC		58	4.10								7.00	3.59		4.10		
Ka COMM	**Ka TRANSMITTER SERVICE TOTAL**	10	58	**81.80**													
COMM	**TOTAL**			**103.80**	**10.00**	**10.00**	**42.00**	**42.00**	**26.42**	**26.42**	**26.42**	**149.42**	**89.56**	**26.42**	**103.80**	**26.42**	**10.00**

Table 4-3. Command and Data Handling (C&DH) Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4.3
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lunar
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Eclipse
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Power
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Avg (W
C&DH	USO 9500, Sat Master	2	113	4.12	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.12	4.00	
C&DH	C&DH	5	113	64.00	13.14	13.14	13.14	13.14	53.14	53.14	53.14	53.14	53.14	53.14	64.00	53.14	13.14
		5	113	68.00	74.29	74.29	76.43	76.43	57.14	60.71	57.14	60.71	57.14	57.14	68.00	57.14	74.29
C&DH	**TOTAL**			**136.12**	**91.43**	**91.43**	**93.57**	**93.57**	**114.28**	**117.85**	**114.28**	**117.85**	**114.28**	**114.28**	**136.12**	**114.28**	**87.43**

Table 4-4. Propulsion Deployment Electronics (PDE) Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lu
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Ec
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Po
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Av
PDE	PDE	2	113	2.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.75	2.50	
		2	113	2.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.75	2.50	
		2	113	2.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.75	2.50	
		2	113	2.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.75	2.50	
PDE	**TOTAL**			**11.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**11.00**	**10.00**	**0**

Table 4-5. Gimbal Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	E
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	I
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	A
Gimbal	Gimbal Controller		113	13.00			14.60	11.40	11.40	11.40	11.40	11.40	11.40	11.40	13.00	11.40	
Gimbal	Actuator		113	6.00			13.00	3.50	3.50	3.50	3.50	3.50	3.50	3.50	6.00	3.50	
Gimbal	Actuator		113	6.00			13.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	6.00	0.40	
GIMBAL	**HGA GIMBAL SERVICE TOTAL**	2	113	**25.00**													
Gimbal	Gimbal Controller		113	13.00			13.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	13.00	9.00	
Gimbal	Actuator		113	6.00			13.00	3.50	3.50	3.50	3.50	3.50	3.50	3.50	6.00	3.50	
Gimbal	Actuator		113	6.00			13.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	6.00	0.40	
GIMBAL	**SA GIMBAL SERVICE TOTAL**	2	113	**25.00**													

Table 4-6. Attitude Control System (ACS) Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4.3
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lunar
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Eclipse
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Power
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Avg (W)
PROP/PDE	**TOTAL**			**128.54**	**0.00**	**0.00**	**504.00**	**0.00**	**0.00**	**649.80**	**0.00**	**649.80**	**51.27**	**0.00**	**0.00**	**43.99**	**0.00**
ACS	Inertial Measurement Unit	2	113	27.50	32.00	32.00	32.00	32.00	25.00	25.00	25.00	25.00	25.00	25.00	27.50	25.00	25.00
ACS	Star Trackers	1	113	12.50				11.20	11.20	11.20	11.20	11.20	11.20	11.20	12.50	11.20	
ACS	Star Trackers	1	113	12.50				11.20	11.20	11.20	11.20	11.20	11.20	11.20	12.50	11.20	
ACS	Reaction Wheel (Generator warning)	5	113	18.00				16.00	16.00	16.00	16.00	16.00	16.00	16.00	18.00	16.00	16.00
ACS	Reaction Wheel	5	113	18.00				16.00	16.00	16.00	16.00	16.00	16.00	16.00	18.00	16.00	16.00
ACS	Reaction Wheels	5	113	18.00				16.00	16.00	16.00	16.00	16.00	16.00	16.00	18.00	16.00	16.00
ACS	Reaction Wheels	5	113	18.00				16.00	16.00	16.00	16.00	16.00	16.00	16.00	18.00	16.00	16.00
ACS	**TOTAL**			**124.50**	**32.00**	**32.00**	**32.00**	**118.40**	**111.40**	**111.40**	**111.40**	**111.40**	**111.40**	**111.40**	**124.50**	**111.40**	**89.00**

Table 4-7. Power Supply Electronics (PSE) Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4.3
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lunar
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Eclipse
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Power
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Avg (W)
POWER	PSE	2	113	53.00	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	53.00	50.43	50.43
POWER	**TOTAL**			**53.00**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**53.00**	**50.43**	**50.43**

Table 4-8. Thermal Power Allocations

	Mission Phase >>			Power	2.1	2.X New	2.X NEW		2.X NEW		2.X NEW	2.X New		3.1,3.2,4.1	3.1,3.2,4.1	4.2	4.3
LRO MASTER	COMPONENTS			Alloc	Pre Launch	Launch	Early Cruise		MID Cruise		Late Cruise	Lunar Orbit Acq		COMMISSIONING		OP	Lunar
EQUIPMENT LIST		(in work)	Duty Cycle	3/13/	Config	T-0 +	Sep	Sun	Transition	MCC	Config	LOI	Orbit	& NOMINAL		orbit	Eclipse
ELECTRICAL	TOTALS are in **BOLD**	Service	Per Orbit	TRA			Config	Acq	Power	Burn		Burn	Circularize	(S)	(S+Ka)	Manuever	Power
Subsystem	POWER PER BOX or NODE	Size (A)	Time (M)	000112	AVG (W)0D	AVG (W)0D	Peak (W)	AVG (W)0D	Avg (W)	Peak (W)	AVG (W)0D	Peak (w)	Avg (W)	Avg (W)	Avg(W)	Avg (W)	Avg (W)
POWER	PSE	2	113	53.00	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	50.43	53.00	50.43	50.43
POWER	**TOTAL**			**53.00**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**50.43**	**53.00**	**50.43**	**50.43**
Thermal Prop	OP GIMBAL HGA	2	113														
Thermal	OP TWT, MOD EPC, TKR, PDE, GCE,	5	113														
Thermal	OP,LOLA, LAMP, CRATER, LROC no	5	113														
Thermal Prop	OP PROP HEATER PRIME, Pressure	10	113														
Thermal		2	113														
Thermal Prop	OP PROP HEATER REDUNDANT,	10	113														
Thermal	WARMUP and RED BAT,C&DH,RWAs	10	113														
Thermal	OP SW CNTL LROC METERING NACR	2	113														
Thermal	OP SW CNTL LROC METERING NACL	2	113														
Thermal	OP GIMBAL SA	2	113														
Thermal	OP DEPLOYMENT HTRS, HGA, SA H	2	113														
Thermal	SURV LOLA, CRTR, DVNR	5	113														
Thermal		2	113														
Thermal	OP Battery, SURV:PDE	5	113														
Thermal	OP C&DH RWAs SURV:LR,TRKR1	5	113														
Thermal	SURV, HGA GIMBALS, SA GIMBALS	5	113														
Thermal	OP: PSE, SBAND, SURV:Mini RF,GCE	5	113														
Thermal	OP ISOTHERMAL SW CNTL via C&DH	2	113														
Thermal	SURV LROC, LOLA, LAMP, ISOTHERI	5	113														
Thermal	OP LEND SW CNTL via C&DH 1 CIRC	2	113														
THERMAL	**TOTAL ESTIMATE**			176.00		112.00	397.00	397.00	397.00		346.00		346.00	147.00	176.00	147.00	423.00
THERMAL	**THERMAL TOTAL**	81			**0.00**	**112.00**	**397.00**	**397.00**	**397.00**	**0.00**	**346.00**	**0.00**	**346.00**	**147.00**	**176.00**	**147.00**	**423.00**

Table 4-9. Propulsion Power Allocations

LRO MASTER EQUIPMENT LIST ELECTRICAL Subsystem	Mission Phase >> COMPONENTS TOTALS are in **BOLD** POWER PER BOX or NODE	(in work) Service Size (A)	Duty Cycle Per Orbit Time (M)	Power Alloc 3/13/ TRA 000112	2.1 Pre Launch Config AVG (W)0D	2.X New Launch T-0 + AVG (W)0D	2.X NEW Early Cruise Sep Config Peak (W)	2.X NEW Early Cruise Sun Acq AVG (W)0D	2.X NEW MID Cruise Transition Power Avg (W)	2.X NEW MID Cruise MCC Burn Peak (W)	2.X NEW Late Cruise Config AVG (W)0D	2.X New Lunar Orbit Acq LOI Burn Peak (w)	2.X New Lunar Orbit Acq Orbit Circularize Avg (W)	3.1,3.2,4.1 COMMISSIONING & NOMINAL (S) Avg (W)	3.1,3.2,4.1 COMMISSIONING & NOMINAL (S+Ka) Avg(W)	4.2 OP orbit Manuever Avg (W)	4.3 Lunar Eclipse Power Avg (W)
PROP	Pyro Valve PV1-A		0.1				504.00										
PROP	Solar Array Release SAR1-A		0.1				504.00										
PROP	Solar Array Release SAR3-A		0.1				504.00										
PROP	High Gain Antenna Release HGAR1-A		0.1				504.00										
PROP	20N Thruster (Divide power numbers by 4) AT1, AT3, AT5, AT7		10	15.50			158.00			158.00		158.00	13.98			13.98	
			30	11.50	←▼2.3		39.20			39.20		39.20	10.41			10.41	
PROP	Latch Valve MLV3-A, MLV4-A HPLV-A		0.1				47.00			47.00		47.00	0.00			0.00	
PROP/PDE	**PDE SERVICE A TOTAL (No Cat Bed**	15	10	**15.50**													
PROP	Pyro Valve PV1-B		0.1				504.00										
PROP	Solar Array Release SAR1-B		0.1				504.00										
PROP	Solar Array Release SAR3-B		0.1				504.00										
PROP	High Gain Antenna Release HGAR1-B		0.1				504.00										
PROP	80N Thruster NT1 and NT3		10	26.02			245.00			245.00		245.00	21.68				
			30	5.75	←▼25.4		19.60			19.60		19.60	5.20			19.60	
PROP	Latch Valve MLV1-A, MLV2-A, TLV1-A, TLV2-A		0.1				47.00			47.00		47.00	0.00			0.00	
PROP/PDE	**PDE SERVICE B TOTAL (No cat Bed)**	15	10	**26.02**													
PROP	Pyro Valve PV2-A		0.1				504.00										
PROP	Solar Array Release SAR2-A		0.1				504.00										
PROP	Solar Array Release SAR4-A		0.1				504.00										
PROP	High Gain Antenna Release HGAR2-A		0.1				504.00										
PROP	20N Thruster (Divide power numbers by 4) AT2, AT4, AT6, AT8		10	15.50			RED									RED	
			30	11.50	←▼2.3		RED									RED	
PROP	Latch Valve MLV3-B, MLV4-B HPLV-B		0.1				47.00			47.00		47.00				0.00	
PROP/PDE	**PDE SERVICE C TOTAL (No Cat Bed**	15	10	**15.50**													
PROP	Pyro Valve PV2-B		0.1				504.00										
PROP	Solar Array Release SAR2-B		0.1				504.00										
PROP	Solar Array Release SAR4-B		0.1				504.00										
PROP	High Gain Antenna Release HGAR2-B		0.1				504.00										
PROP	80N Thruster NT2 and NT4		10	26.02			RED									RED	
			30	5.75	←▼25.4		RED									RED	
PROP	Latch Valve MLV1-B, MLV2-B, TLV1-B, TLV2-B		0.1				47.00			47.00		47.00				0.00	
PROP/PDE	**PDE SERVICE D TOTAL (No Cat Bed**	15	10	**26.02**													
PROP	**CAT BED SERVICE A TOTAL**	2	30	**17.25**													
PROP	**CAT BED SERVICE B TOTAL**	2	30	**17.25**													
PROP/PDE	**TOTAL**			**128.54**	**0.00**	**0.00**	**504.00**	**0.00**	**0.00**	**649.80**	**0.00**	**649.80**	**51.27**	**0.00**	**0.00**	**43.99**	**0.00**

5.0 DELTA V / FUEL ALLOCATION

The overall Orbiter mass allocation is traced from the Lunar Reconnaissance Orbiter Mission Requirements Document (431-RQMT-000004, requirement MRD-24).

The Mid-Course Correction (MCC) allocation was determined from the MRD requirements, MRD-3, MRD-10 and MRD-25. This assumes a MCC at launch + 24 hours.

The station-keeping allocation was determined from the MRD requirements MRD-12 and MRD-13.

The extended mission was derived from the MRD requirement MRD-22. The delta V for the extended mission is a placeholder while extended mission options are traded. This allocation could be used for contingency if the mission required it.

Further assumptions include that all Lunar Orbit Insertion burns (1 through 4) are performed with the 20 lbf thrusters (Isp=220) and that the remaining operations are performed with the 5 lbf thrusters (Isp=224).

Table 5-1. Delta V / Fuel Mass Allocation

Mission Phase	LRO Baseline dV (m/sec)	Fuel Mass (kg)	Comments
MCC	28	26.37	3σ, MCC @ L+24 hours
Thruster Check-out	-	.23	
Lunar Insertion – 1st burn	547	444.9	
Lunar Insertion – 2nd burn	185	121.8	
Lunar Insertion – 3rd burn	133	81.3	
Lunar Insertion – 4th burn	41	24.1	
Mission Orbit Insertion	50	28.8	
Station-keeping	150	84.1	
Extended Mission	65	33.5	
Momentum Unloading	-	17.0	
Unallocated Margin	39	20.9	
Residual Propellant		12.0	
Total	**1258**	**895**	

6.0 DATA CAPTURE BUDGET

6.1 OBSERVATION INTERRUPTION SUMMARY

Table 6-1 provides the expected observation time during the nominal mission phase.

Table 6-1. Data Observations

LRO Measurement Interruptions Summary			
Nominal Measurement Phase:		*1*	*Year*
Number of Lunar Orbits During Measurement Phase:		*4651*	*Orbits*
Activity	Interval (Months)	Duration (Orbits)	Total (Orbits)
Momentum Management Operations	0.5	1	24
Station-Keeping Maneuvers	1	1	12
Instrument Cals (including Mni-RF)	1	3	36
Yaw Maneuvers	6	1	2
Lunar Eclipses	6	3	6
Sun-Safe/Contingency Allocation	12	154	154
Total Orbit Allocation for Nominal Phase:			*234*
Percentage of Interruption Time:			*5.0%*
Percentage of Measurement Observations:			*95.0%*
Allocation without Sun-Safe/Contingency:			*80*
Percentage of Interruption Time (w/o Sun-Safe):			*1.7%*
Percentage of Measurement Observations (w/o Sun-Safe):			*98.3%*

The following provide some additional details regarding the measurement observation time:

- Based on 1-year nominal mission; assumes interruptions for two lunar eclipses in 2009 (which may not interrupt measurement operations)
- Current budget allows for 154 orbits, ~12 days, of Sun-Safe/Contingency operations before MRD requirement of 95% collection efficiency is exceeded
- Without contingency allocation, LRO observation time is expected to be ~98.3%

6.2 DATA CAPTURE BUDGET

As shown in Table 6-1, LRO will be in collecting measurement data at least 95% during nominal mission phase. The data capture budget provides the performance on how much data collected during the 95% will be delivered to the instrument science operations center. The Lunar Reconnaissance Orbiter Mission Requirements Document (431-RQMT-000004) provides a requirement on the orbiter and ground system to deliver a minimum of 98% of collected science data. For the system, 0.5% was allocated to the spacecraft and 1.5% was allocated to the ground system.

Spacecraft errors are due to bit error rate (BER) on the data interfaces and memory storage. The BER for the spacecraft were calculated based on the following assumptions:

- SpaceWire bus has a BER of 1e-13
- Disk Interface Board has a BER of 1e-13
- 1553 bus is error free
- Compact Peripheral Component Interconnect (cPCI) point-to-point is error free
- Downlink BER is 1e-9, but is error free due to Consultative Committee for Space Data Systems (CCSDS) File Data Protocol (CFDP)
- Ground system BER is error free due to transfer protocol and temporary file storage

Table 6-2 provides the breakdown of expected data loss due to the spacecraft and ground systems.

Table 6-2. Data Capture/Delivery Budget

Data Source	Daily Data (Gbits)	Est. Daily S/C Errors	Est. RF Link Errors (1)	Est. Daily Grnd Errors (2)	Error Intervals (Days)	Data Loss per year (Mbytes)	End to End Data Delivery %
CRaTER	7.76	0.00155	0.00	0.0000	644.2	0.0005	99.99999992%
Diviner	3.49	0.00070	0.00	0.0000	1430.7	0.0012	99.99999981%
LAMP	0.94	0.00028	0.00	0.0000	3545.6	0.0657	99.99998422%
LEND	0.26	0.00005	0.00	0.0000	19120.2	0.0004	99.99999993%
LOLA	1.40	0.00028	0.00	0.0000	3563.4	0.0020	99.99999968%
LROC NAC	515.13	0.15454	0.00	0.0000	6.5	15,032.3855	99.93557549%
LROC WAC	40.84	0.01225	0.00	0.0000	81.6	0.3029	99.99998546%

(1) CFDP provides error free delivery
(2) Transfer protocols provide error free delivery

What is not accounted for in the budget is the ground station performance factor which includes the following:

- Ground station equipment error
- Solar Radio Frequency Interference (RFI)
- White Sands Complex (WSC) RFI
- Operator error
- Weather

Solar RFI, WSC RFI, operator error and equipment error does not contribute to the overall loss since on average; losses are less than the spacecraft storage allocation. Data will not be lost but data latency will increase. Weather at WSC could have data loss budget, on average ~80 hours (hrs) at WSC will be lost due to weather in one year. While weather is unpredictable, any data delivery loss is easily accounted in the 1.5% allocation and/or contingency allocation in observation budget.

7.0 1553 DATA BUDGET

The Digital Time Division Command/Response Multiplex Data Bus (MIL-STD-1553B) is specified as a 1 Megahertz (MHz) bus. While the clock speed of the 1553 Bus is 1 MHz, transmission overhead, re-try allocation, and less than optimal data transfers result in using 300 kilobits per second (Kbits/sec) as its total data allocation.

In an effort to account for growth in the allocation estimates, it is a design goal to have a 30% margin at the Flight Software Requirements Review milestone.

Table 7-1. 1553 Bus Allocation

Subsystem	Total Bits/Sec per Subsystem	Percentage of Total Resource %	Comments
C&DH (MAC)	2672	0.89%	
Power (PSE)	6518	2.17%	
Comm	1862	0.62%	
SA Gimbal Controller		0.00%	
HGA Gimbal Controller		0.00%	
GN&C	30250	10.08%	
CRaTER	90267	30.09%	
DRLE	26688	8.90%	
LEND	3083	1.03%	
LOLA	27616	9.21%	Includes LR
AllocationTotal:	**188956**	**62.99%**	
Resource Total:	**300000**		

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ACS	Attitude Control System
BER	Bit Error Rate
C&DH	Command and Data Handling
CBE	Current Best Estimate
CCB	Configuration Control Board
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Data Protocol
CM	Configuration Management
CMO	Configuration Management Office
COMM	Communication
cPCI	compact Peripheral Component Interconnect
CPU	Central Processing Unit
CRaTER	Cosmic Ray telescope for Effects of Radiation
dB	Decibel
DDA	Disk Drive Assembly
Delta V	Delta Velocity
DLRE	Diviner Lunar Radiometer Experiment
EELV	Evolved expendable launch vehicle
EEPROM	Electrically Erasable Programmable Read Only Memory
EOL	End of Life
Est.	Estimate
FSW	Flight Software
GN&C	Guidance, Navigation, and Control
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
HQ	Headquarters
Hrs	Hours
HTR	Heater
I/F	Interface
ICD	Interface Control Document
Isp	Specific Impulse
Kbits/sec	Kilobits per second
Kg(s)	Kilogram(s)
LAMP	Lyman-Alpha Mapping Project
LB	Pounds

Abbreviation/ Acronym	DEFINITION
lbf	Pound Force
LEND	Lunar Exploration Neutron Detector
LOIS	Lunar Orbit Insertion Stage
LOLA	Lunar Orbiter Laser Altimeter
LR	Laser Ranging
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
LV	Launch Vehicle
Mbytes	Megabytes
m/sec	Meters per Second
MCC	Mid-Course Correction
MEL	Master Equipment List
MHz	Megahertz
MLI	Multilayer insulation
MRD	Mission Requirements Document
NAC	Narrow Angle Camera
NASA	National Aeronautics and Space Administration
NTC	Nutation Time Constant
OM	Output Module (PSE card)
PDE	Propulsion Deployment Electronics
PDR	Preliminary Design Review
PROC	Procedure
PROM	Programmable Read Only Memory
Prop	Propellant
PSE	Power System Electronics
RAM	Random Access Memory
Rec	Receive
RF	Radio Frequency
RFI	Radio Frequency Interference
RQMT	Requirement
S/C	Spacecraft
SA	Solar Array
SCS	Sequence and Compressor System (LROC)
SPEC	Specification
SRM	Solid Rocket Motor
SRR	Systems Requirement Review
SSR	Solid State Recorder
STD	Standard
SW	Switched

Abbreviation/ Acronym	DEFINITION
TCS	Thermal Control System
TDRSS	Tracking and Data Relay Satellite System
TT&C	Tracking, Telemetry, & Commanding
UART	Universal Asynchronous Receiver / Transmitter
US	Un-switched
W	Watt
WAC	Wide Angle Camera
Wrt	With respect to
WSC	White Sands Complex
Xmit	Transmitter
XPDR	Transponder

Appendix B. Mass Allocation History

Table B-1. Mass Allocation History – LRO PDR to LRO CDR

Subsystem	CBE at Feb-06 (kg)	CBE at Mar-06 (kg)	CBE at Apr-06 (kg)	CBE at May-06 (kg)	CBE at Jun-06 (kg)	CBE at Jul-06 (kg)	CBE at Aug-06 (kg)	CBE at Sep-06 (kg)	CBE at Oct-06 (kg)
Dry Mass	**730.7**	**729.8**	**773.8**	**798.0**	**798.0**	**806.2**	**848.7**	**837.5**	**856.5**
ACS Hardware	58.6	58.6	58.6	58.6	58.6	58.6	60.9	61.1	61.1
Battery	30.0	30.0	37.0	37.0	37.0	37.0	37.0	34.5	35.2
C&DH	21.2	21.2	21.2	24.9	24.9	24.9	24.9	24.9	24.9
Harness	40.0	40.0	40.0	40.0	40.0	40.0	74.9	74.9	71.7
High Gain Assy.	38.2	38.2	44.7	44.7	44.7	50.7	52.8	50.3	50.1
Ka Comm	7.1	6.2	6.2	6.2	6.2	6.2	6.2	6.5	7.7
Prop Deploy Elec (PDE)	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	9.7
Propulsion (Dry Mass)	136.1	136.1	138.5	138.5	138.5	140.6	140.6	140.6	140.6
Power Supply Elec (PSE)	16.1	16.1	16.2	16.2	16.2	16.2	16.2	17.0	17.0
S/C Bus Structure	258.9	258.9	286.9	286.9	286.9	286.9	286.9	226.1	244.3
S-Band Comm	10.7	10.7	10.7	10.7	10.7	10.7	10.7	9.2	9.2
Solar Array Assembly	75.8	75.8	75.8	96.3	96.3	96.3	99.6	97.4	101.9
Laser Ranging	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.5	0.5
Thermal	22.8	22.8	22.8	22.8	22.8	22.8	22.8	80.6	82.7
Instrument	**79.9**	**79.9**	**82.1**	**82.1**	**82.1**	**82.1**	**86.9**	**86.9**	**89.1**
CRaTER	5.6	5.6	5.6	5.6	5.6	5.6	5.3	5.3	5.3
Diviner	9.98	9.98	12.12	12.12	12.12	12.12	12.1	12.1	12.1
LAMP	5	5	5.02	5.02	5.02	5.02	4.8	4.8	4.8
LEND	23.7	23.7	23.7	23.7	23.7	23.7	24.0	24.0	24.0
LOLA	10.73	10.73	10.73	10.725	10.725	10.725	10.7	10.7	13.1
LROC	14.4	14.4	14.44	14.44	14.44	14.44	17.1	17.1	17.1
Mini-RF	10.5	10.5	10.5	10.5	10.5	10.5	12.9	12.9	12.7
Cosumables	**897.5**	**897.5**	**897.5**	**897.5**	**897.5**	**898.2**	**898.2**	**898.2**	**898.4**
Fuel + Pressurant	897.5	897.5	897.5	897.5	897.5	898.2	898.2	898.2	898.4

Table B-2. Mass Allocation History – LRO SRR to LRO PDR

LRO MASTER EQUIPMENT LIST Subsystem	CBE at Apr-05 (kg)	CBE at May-05 (kg)	CBE at Jun-05 (kg)	CBE at Aug-05 (kg)	CBE at Nov-05 (kg)	CBE at Jan-06 (kg)	Comments
Dry Mass	**502.2**	**526.8**	**532.1**	**523.4**	**656.0**	**691.0**	
ACS Hardware	42.6	46.6	58.6	58.6	58.6	58.6	
Battery	30.0	30.0	30.0	30.0	30.0	30.0	
C&DH	15.7	15.7	15.7	15.7	21.2	21.2	
Harness	25.0	25.0	32.0	32.0	32.0	36.0	
High Gain Assy.	21.0	21.0	35.5	36.0	35.9	38.2	
Ka Comm	4.3	5.3	16.7	5.2	7.7	6.2	
Prop Deploy Elec (PDE)	15.0	19.6	14.0	14.0	14.0	14.0	
Propulsion (Dry Mass)	66.9	66.9	95.6	95.6	109.5	128.6	
Power Supply Elec (PSE)	13.0	11.8	11.8	13.6	14.9	14.9	
S/C Bus Structure	203.0	203.0	142.0	142.0	192.3	232.9	
S-Band Comm	9.0	9.0	10.7	10.7	8.3	10.7	
Solar Array Assembly	32.8	39.0	41.7	42.2	68.5	75.8	
Laser Ranging	0.0	0.0	0.0	0.0	35.3	1.2	LOIS / SRM thru 11/30
Thermal	24.0	34.0	27.8	27.8	27.8	22.8	
Instrument	**68.8**	**79.3**	**66.4**	**76.5**	**79.8**	**79.9**	
CRaTER	5.6	5.6	5.3	5.3	5.6	5.6	
Diviner	10.0	10.0	9.8	9.8	10.0	10.0	
LAMP	5.0	5.0	4.9	4.9	5.0	5.0	
LEND	23.2	23.2	20.0	20.0	23.7	23.7	
LOLA	10.6	10.6	12.5	12.4	10.6	10.7	
LROC	14.4	14.4	13.6	13.6	14.4	14.4	
Mini-RF	0.0	10.5	0.5	10.5	10.5	10.5	
Wet Mass	**701.0**	**714.3**	**715.3**	**715.3**	**625.1**	**893.0**	
Propellant (Wet)	701	714.3	715.3	715.3	625.1	893.0	11/30 includes SRM dry propellant

Appendix C. Power Allocation History

Table C-1. Power Allocation History – LRO PDR to LRO CDR

		2/7/2006	3/14/2006	4/11/2006	5/2/2006	6/1/2006	7/1/2006	8/1/2006	9/1/2006	10/1/2006
CBE AND ALLOCATION TRACKING DOCUMENT										
		β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE
Subsystem	Components	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)
Instrument	INSTRUMENT TOTAL	106.54	106.54	107.11	107.11	120.9	121.51	122.81	117.61	119.51
Comm	COMM TOTAL	98.28	98.28	98.28	98.28	98.28	98.28	98.28	98.28	89.56
C&DH	C&DH TOTAL	105.29	105.29	136.43	136.43	136.43	136.43	136.43	136.43	114.28
Gimbal	GIMBAL TOTAL	40	40	25.8	25.8	25.8	25.8	25.8	25.8	31.8
PDE/PROP	PROPULSION TOTAL	8	8	8	8	8	8	8	8	10
ACS	ACS TOTAL	123	123	123	123	123	123	123	123	107.4
Power (PSE)	PSE TOTAL	45	45	45	45	45	45	45	51	51
Thermal	Thermal TOTAL	126	126	151.2	108	113	113	113	113	147
	TOTAL	652.11	652.11	694.82	651.62	670.41	671.02	672.32	673.12	670.55

Table C-2. Power Allocation History – LRO SRR to LRO PDR

		1/11/2005	2/28/2005	3/16/2005	4/19/2005	5/16/2005	6/14/2005	7/14/2005	8/8/2005	9/27/2005	10/11/2005	11/18/2005	12/15/2005	1/18/2006
CBE AND ALLOCATION TRACKING DOCUMENT														
		β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE
Subsystem	Components	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)
Instrument	INSTRUMENT TOTAL	87.5	82.5	82.5	88.5	94.5	102.6	89.42	117.02	118.12	118.12	121.14	115.44	106.54
Comm	COMM TOTAL	23.1	52.5	53	55	55	55	74.68	74.68	74.68	74.68	79.33	81.29	98.28
C&DH	C&DH TOTAL	80	95.3	95	95	95	95	95	95	63	63	105.29	105.29	105.29
Gimbal	GIMBAL TOTAL	15	40	40	40	40	40	40	40	40	40	40	40	40
PDE/PROP	PROPULSION TOTAL	5	3	9	33	33	33	33	33	6	6	10	32	8
ACS	ACS TOTAL	80.6	110	82	82	82	82	96	96	96	96	120	123	123
Power	PSE TOTAL	39	22	22	22	40	40	40	40	45	45	45	45	45
Thermal	Thermal TOTAL	80	138.4	178.4	247.4	247.4	287.4	287.4	305.5	346	346	346	126	126
	TOTAL	410.20	543.70	561.90	662.90	686.90	735.00	755.50	801.20	788.80	788.80	866.76	668.02	652.11
Max Power	Beta 0	823	823	823	823	823	823	823	823	823	823	823	823	823
	NON-STANDARD ORBIT ALLOCATIONS	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE	β 0 CBE
		O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)	O Avg (W)
Instrument	LROC Optics Decontamination	0.00			110.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00	98.00
ACS	CAT BED HEATERS	0.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	18.00	18.00	11.72	11.72	17.84
ACS	CAT BED HEATERS	0.00								18.00	18.00	11.72	11.72	17.84
ACS	THRUSTER PDE CIRC A	0.00	20.80	20.80	20.40	20.40	20.40	20.40	20.40	26.00	26.00	15.00	14.94	55.94
ACS	THRUSTER PDE CIRC B	0.00								26.00	26.00	15.00	14.94	55.94