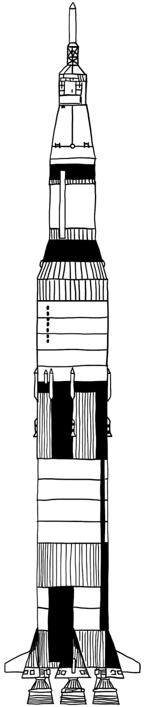
Pandora Space: Saturn V

Conceptual Design Review

ARO11L Section 01 Team #5, Pandora Space
Date Submitted: Monday, February 15, 2021

Team Lead 1: Ashley Perez
Team Deputy 1: Jason Perez
Members: Rukie Shendaj, Kenneth Garcia, Jonathan Sosa-Roman, Trung La, and Nimrod Castano



ARO 2011L-01
Cal Poly Pomona Aerospace Engineering Department

Participation

Ashley Perez - 100%

Jason Perez - 100%

Rukie Shendaj - 100%

Johnathan Sosa - 100%

Trung La - 100%

Nimrod Castano - 100%

Kenneth Garcia - 100%

1.1 Needs Analysis

The key <u>external</u> stakeholders and their needs are:

Customer needs: NASA, needs a launch vehicle system to be able to launch the lunar lander into the moons orbit and rendezvous with the surface of the moon.

Public sector needs: Primarily the American people are impacted by the Saturn V as they are represented by the nations endeavours and need the Saturn V to land a man on the moon because America is currently losing a very tense Cold War

Government agency needs: NASA is the main government agency impacted by the development of the Saturn V, they need to organize a large multi-company effort involving thousands of people in order to successfully design and manufacture the Saturn V.

Other external stakeholder needs: The science and technology communities all over the world are impacted by this system as it will allow for the collection of previously unobtainable data, that may lead to advancements in the technology of the future.

NEED: The US space program is currently losing the space race to the Russians. We need to land a man on the moon before the Russians to demonstrate that the U.S. is the most advanced and powerful nation in the world.

1.1 Needs Analysis - Cont.

- **The key internal stakeholders and their needs are:**

  The internal stakeholders are our design and manufacturing partners and their needs are open lines of communication and collaboration with Pandora Space.

- **Why does your company or agency need to participate in creating this system?**

  Pandora Space is aiming to be the main designer and manufacturer of rockets for NASA lunar missions. We believe our system engineering process is essential to ensure the safe completion in the mission.

- **Why do the company employees need to participate in creating this system?**

  By developing the Saturn V system, Pandora Space will be on the forefront of rocket design and technology. We need the support of our hundreds of employees to help us with the daunting task of designing a launch vehicle with lunar capabilities.

- **Identify other internal stakeholders and why they need/impacted by this system**

  Three internal stakeholders of this system are Boeing, Douglas Aircraft Company and North American Aviation who will assist in designing and manufacturing the system.

1.2 Program Goals

The primary customer goals of the program are:

-Develop a space program "NASA" which is the most advanced space program in the world. Put a man on the moon by the end of the decade in order to beat the Soviet Union in the space race and demonstrate global dominance as Cold War tensions continue to rise.

The primary company goals of the program are:

-Design, develop, test and manufacture a new rocket for NASA that will carry the Lunar Lander and the first men to the moon by the end of the decade.

-Design a Rocket that will carry the lunar lander in some component of the rocket that has the capability of orbiting the moon, amd returning, to ensure that an attempt at a moon landing is safe

This improved launch vehicle will be able to reach the moon by utilizing state-of-the-art technology, and this time it will have astronauts onboard who will walk on the moon then return safely to Earth.

1.3 Program Objectives

Customer Objectives	Company Objectives
Hire a company with developed knowledge of astronautics and rocket propulsion to design a safe launch vehicle with lunar capabilities and heavy payload to LEO capabilities	Win the NASA contract to design a safe launch vehicle with lunar capabilities.
Create a cost-effective program to get to the moon without exceeding entire given budget	Develop an abort system with detail at every phase of the mission in order for the astronauts to have the highest chance of survival.
Become the leading experts in, space travel, high thrust launch vehicles, orbital dynamics, orbital rendezvous of two spacecrafts.	Develop the abilities of our companies managers, engineers, and technicians, in order to more efficiently conduct future business
Ensure that the proposed architecture can be developed, and manufactured before the end of the decade.	Down-select moon mission architectures in PDR to find the path of flight and lading that quill require the least fuel and energy.

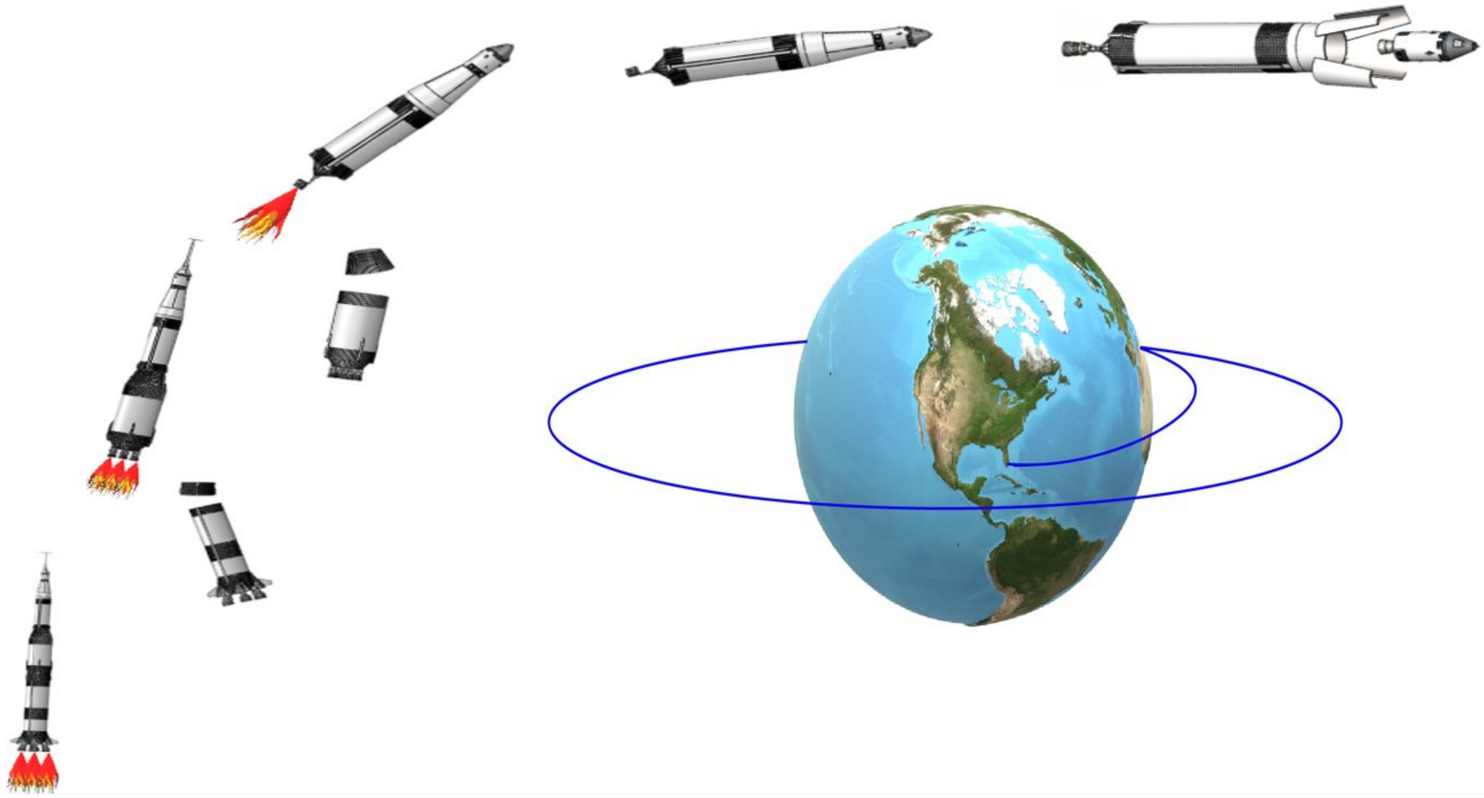
1.4-1a Design Reference Mission #1: Apollo 7 / General Launch to LEO

- Stage 1 provides enough thrust to get the manned payload through max dynamic pressure (MAXQ)
- Stage 2 provides enough thrust to propel the payload into high atmosphere
- Stage 3 provides enough thrust to reach and maintain orbit and propels the manned command service module (CSM) or payload into (LEO) low earth orbit
- A crucial step into catching the Russians in the space race, they have a satellite orbiting the earth

The launch vehicle will be able to transport a manned CSM or large payload to LEO by meeting the above specifications. This is crucial to overtaking the Russians in the Space Race.

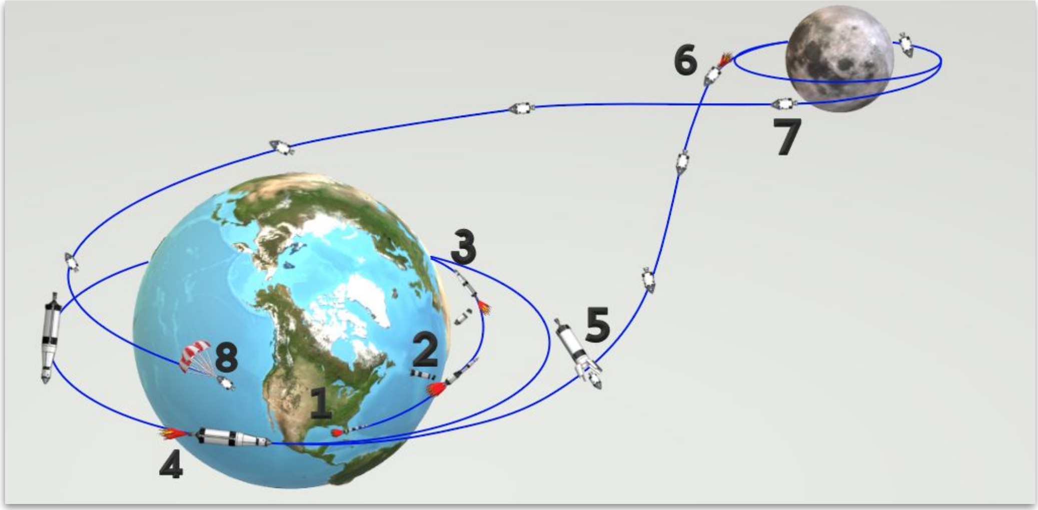
1.4-1b Design Reference Mission #1:

Apollo 7 Mission Profile, and LEO visulaization Graphic



1.4-2 Design Reference Mission #2: Apollo 8

- The launch vehicle will launch from Florida into an Earth Parking Orbit (EPO)
- After Stage 3 boosts out of the EPO, the Command Service Module (CSM) will be launched toward the moon
- The CSM will slow down with a back boost and orbit the moon And boost again to leave orbit and return to earth's ocean
- Apollo 8 will give the US the lead in the space race by being the first to orbit the Moon



The launch vehicle will use EPO to deliver the manned CSM around the moon.
The US will lead the Space Race and Demonstrate Dominance over Russians.

1.5a-1 System Level Requirements

RFP Para #	Req. #	WBS #	FOM#	Requirement Statement	Validation Method by CoDR	Met at CoDR/SDR?
1.0	T0.0-1	0.0	N/A	System must prioritize crew safety with a loss of mission ratio no greater than 1/10,000 for all segments of the mission	Test with current rockets and scale up from those.	Yes
2.0	T0.0-2	0.0	1	System must have max thrust exceeding 9,000,000 lbs to launch the entire mass of the launch vehicle into space and into orbit.	Test with current rockets and scale up from those.	Yes
3.0	T0.0-3	0.0	2	System must be capable of Trans Lunar Insertion (TLI) 100 km above the lunar surface with safe return to earth	Monitor Spaceflight Tracking data	Yes
4.0	T0.0-4	0.0	3	System must be able to track it's own flight parameters with 99% accuracy for all segments of the mission	Partnership with IBM to improve computer technology	Yes
4.11	T0.0-5	0.0	4	System must be able to be tracked within a 100m radius for all segments of the mission	Current Radar Technology	Yes

1.5a-2 System Level Requirements

RFP Para #	Req. #	WBS #	FOM#	Requirement Statement	Validation Method by CoDR	Met at CoDR/SDR ?
5.1	C0.0-2	0.0	5	System must be able to launch payload for less than $200,000 per pound	Cost and payload capabilities analysis	
5.2	C0.0-3	0.0	N/A	Mission must cost less than money allocated for research and development with current NASA budget ($60 billion in 1964)	Appropriation costs prior to production	Yes
6 .0	M0.0-1	0.0	6	System will go from paper to product in less than 9 years in order to launch before end of decade and beat the Russians	Hire multiple companies to assist in design and production	Yes
6.1	M0.0-2	0.0	7	System must weigh less than 7,000,000 lbs in order to be launched at Kennedy Space Center, Florida	Size and weight / thrust analysis	Yes
6.2	M0.0-3	0.0	8	System will be launched 15 times, within 7 years In the US	Ensure manufacturers have capabilities to produce at this rate	Yes

1.5b-1 Derived Requirements

Derived Req #	Derived from System Level Req.#	WBS #	Derived Requirement Statement	Validation Method by CoDR	Met at CoDR/SDR?
TR1.1-1	T0.0-1	0.0	System launch to LEO must have mission fail ration no greater than 1/100	Risk analysis of all engines firing in earth's atmosphere	Yes
TR1.1-2	T0.0-1	0.0	System must be capable of escape from moon's gravity with mission fail ratio no greater than 1/1000	Orbital dynamics calculations and Risk Analysis of engine used to return to earth	Yes
TR1.1-3	T0.0-1	0.0	System will have a Launch Escape Vehicle (LEV) with mission success of 99.99% in returning crew to earth	Develop branch for LEV development	Yes
TR1.1-4	T0.0-1	0.0	Each stage of system will be tested and maintained by their respective manufacturers	Contract agreement with companies hired for development and manufacturing	Yes
TR1.1-4.2	T0.0-1	0.0	The system will be assembled and tested in its entirety at Kennedy Space Center	Vertical Assembly Building will be created	Yes

1.5b-2 Derived Requirements

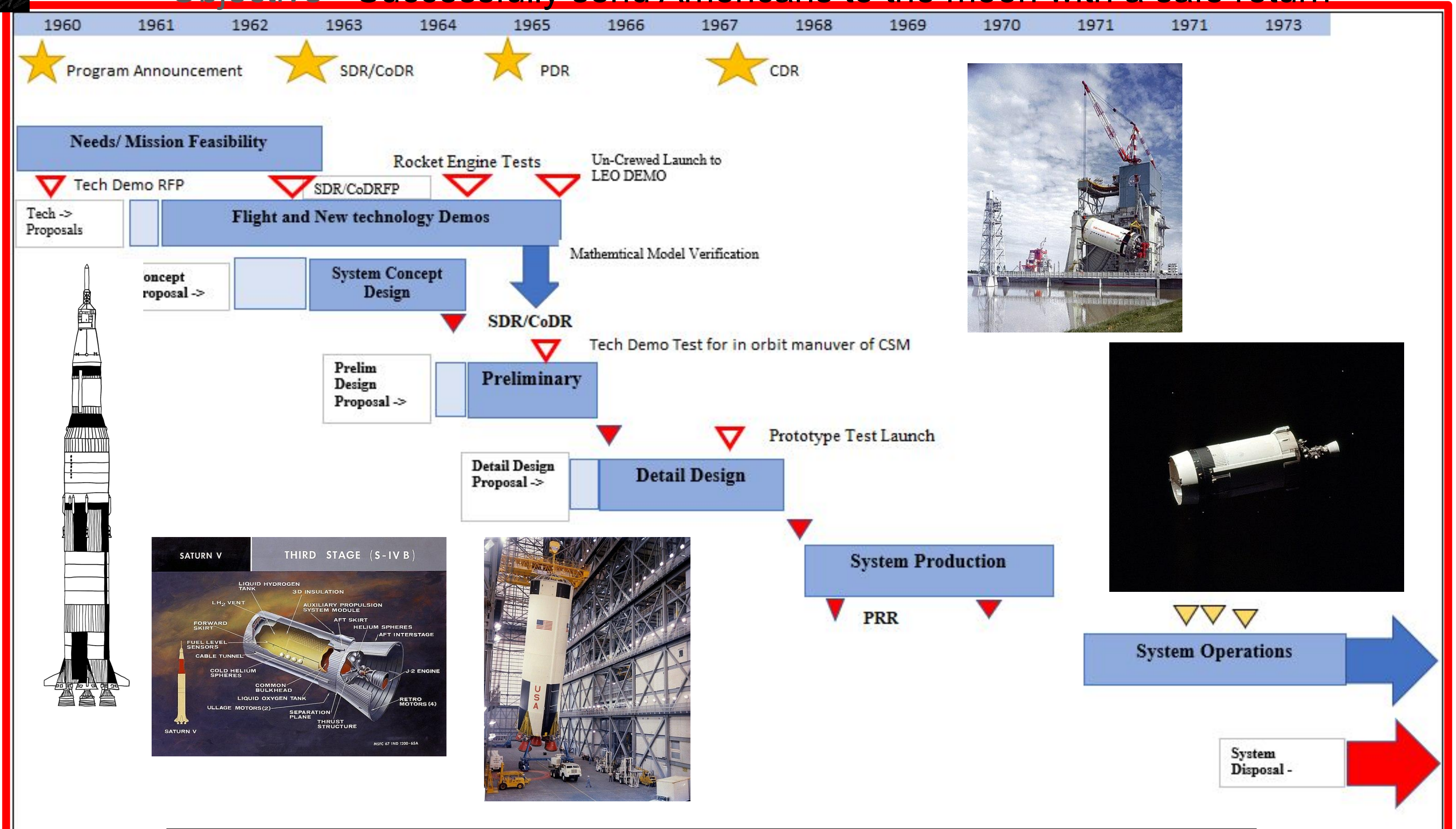
Derived Req #	Derived from System Level Req.#	WBS #	Derived Requirement Statement	Validation Method by CoDR	Met at CoDR/SDR?
TR2.1-1	T0.0-2	0.0	Multi stage design with 1st stage capable of producing 7,500,000 lbs of thrust to get system out of low earth atmosphere	Rocket engine research and development	Yes
TR2.1-3	T0.0-2	0.0	2nd stage Capable of producing 1,100,000 pounds of thrust to get system out of atmosphere	Rocket engine research and development	Yes
TR2.2-1	T0.0-3	0.0	3rd stage will have one engine with 200,000 lbs of thrust to propel CSM to TLI	Risk analysis of all engines firing in earth's atmosphere	Yes
TR2.3-1	T0.0-4	0.0	System will utilize a large computer system instrument unit (IU) which tracks 200 flight parameters for all segments of the mission	Partnership with IBM	Yes
TR2.3-2	T0.0-1	0.0	System will have a C-band radar transponder to track the systems trajectory within 100m radius	Current Radar Technology	Yes

1.5b-3 Derived Requirements

Derived Req #	Derived from System Level Req.#	WBS #	Derived Requirement Statement	Validation Method by CoDR	Met at CoDR/SDR?
CR1.1-1	C0.0-2	0.0	Development and research for new technologies. (IU, CSM, LEV) will not cost more than 25% of total budget	Rocket engine research and development	Yes
CMR2.1-3	C0.0-2 M0.0-2	0.0	The entire system will weigh at maximum 6,200,000 lbs in order to meet the launch cost and weight max requirements	Mass estimation of all stages and payloads and propellants	Yes

1.6 Life Cycle Schedule for Saturn V

Objective - Successfully send Americans to the moon with a safe return



Saturn V will be developed in 6 years and will retire in 12 years.

2.0 Organization Chart for CoDR/SDR Chart

0.0 Team Lead
Chart

Ashley Perez

0.1 Team Deputy

Deputy: Jason Perez

1.0 Chief Systems Engineer Charts

Kenneth Garcia
Deputy: Jonathan Sosa-Roman

2.0 Chief Architect Charts

Rukie Shendaj
Deputy: Nimrod Castano

3.0 Work Breakdown Structure Lead

Nimrod Castano
Deputy: Jason Perez

4.0 Operations Analyst
Charts

Jonathan Sosa-Roman
Deputy: Ashley Perez

5.0 Maintenance & Support Lead
Charts

Trung La
Deputy: Kenneth Garcia

Our highly skilled engineers have designed and successfully launched two previous launch vehicles capable of being scaled up to achieve lunar orbit.

2.1 Org Chart Responsibility Charters

- **0.0 Team Lead** - develops the teams' skills and manages the project, while making executive decisions regarding the final product
- **0.1 Team Deputy** - assists the team lead with project management and delegating team tasks
- **1.0 Chief Systems Engineer** - oversees launch vehicle development, manufacture, and testing
- **2.0 Chief Architect** - oversees the mission design and development through conception to meeting the mission objective
- **3.0 Work Breakdown Structure Lead** - manages the mission schedule and timeline to meet or exceed deliverable deadlines
- **4.0 Operations Analyst** - ensures the smooth functioning of the team by determining ideal workflow conditions and resolving and outstanding issues interfering with mission progress (charts 6.0, 7.0a, 7.0 b)
- **5.0 Maintenance & Support Lead** - oversees the implementation of all technical and logistic aspects of launch vehicle manufacture and transportation (charts 6.0, 7.0a, 7.0 b)

Key personnel duties have been clearly outlined to ensure a timely and efficient workflow at all levels of the mission.

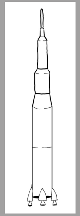
3.1 System Candidate Architectures for Feasibility Analysis

Need for System: Low cost Launch Vehicle Capable of propelling Lunar Vehicle to the moon and back which can be completed in a timely manner.

System Architecture #1- "Saturn C-5"

Attributes:

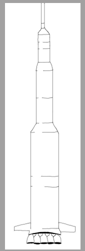
1. 5xF1 Engines
2. 3 Stage Rocket
3. Maximum payload of 320,000 lb to LEO
4. $185 million per launch
5. 7.5 Million lbs of thrust (1st stage)
6. Lox/Kerosene/LH2



System Architecture #2- "Nova C8"

Attributes:

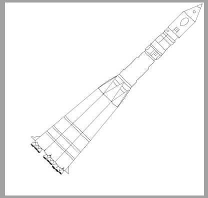
1. 8xF1 Engines
2. 3 Stage Rocket
3. Maximum payload of 460,000 lb to LEO
4. $300 million per launch
5. 13.9 million lbs of thrust (1 stage)
6. Lox/Kerosene/LH2



System Architecture #3- "N1"

Attributes:

1. 30xNK-15 Rocket Engines
2. 3 Stage Rocket
3. Maximum payload of 209,000 lb to LEO
4. $230 million per launch
5. 10 million lbs of thrust (1 stage)
6. Lox/Kerosene/Syntin



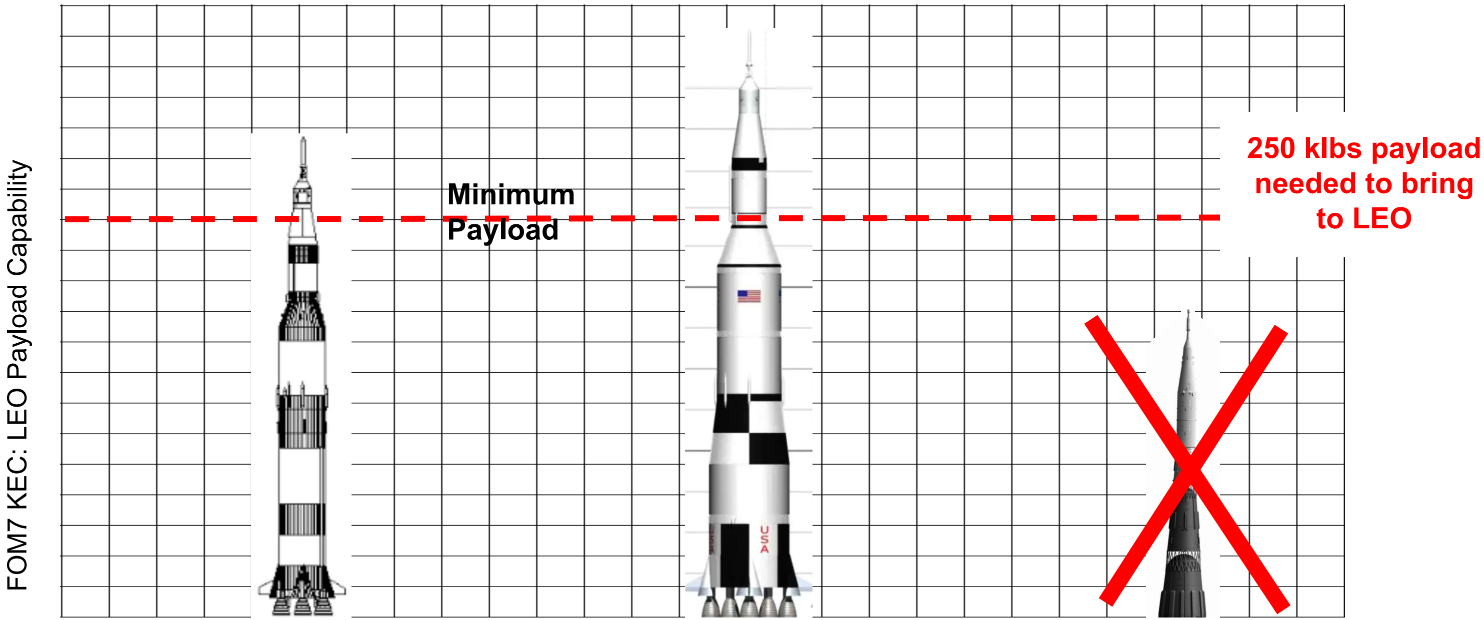
All proposed architectures meet requirements established by NASA.

3.2 System Level Figures of Merit & Key Evaluation Criteria (for Feasibility Analysis)

SLR #	FOM No.	Description (Units)	Target Value/ or Characteristic	Importance Rank	Weight Factor WF*
C0.0-3	1	Budget (Total cost for development)	$ 60 billion	6	1
TR2.1-1	2	Total thrust	9 million lb	5	2
T0.0-3	3	Lunar orbit Capabilities	100 km above surface of the moon	4	2
T0.0-4	4	Control center (Communication/Tracking Capabilities)	100 m radius	3	2
M0.0-1	5	Completion Window (End of Decade, Rocket Completed in shortest time)	9 Years	2	3
T0.0-1	6	Safety Rating (More Engines lower Safety Rating)	<1.4 Factor of Safety	1	3
T0.0-3	KEC 7	LEO Payload capability	250 klbs	Go/No-Go Eval. Criteria	Not Scored

Safety is our main priority. But we are also making sure that our system will have enough thrust to carry at least 250,000 lbs of payload to LEO.

3.3a Feasibility Analysis: Quick Screening of Alternatives Using FOM Key Evaluation Criteria (KEC): LEO Payload Capability



Arch #1: Saturn C-5
Payload: 320 klbs

Arch #2: Nova C8
Payload: 460 klbs

Arch #3: N1
Payload: 209 klbs

The N1 will be unable to carry enough payload to the moon so it is rejected as a potential design.

3.3b Remaining System Candidate Architectures for

The 2 remaining system architectures include a combination of payload and thrust capability that ensure the final selected system will best satisfy the system level requirements and meet the deadline to launch before the end of the decade.

System Architecture #1
Attributes:

1. 5 F1 Engines
2. 3 Stage Rocket
3. Max payload 320,000 lbs to LEO
4. $185 million per launch
5. 7.5 Million lbs of thrust (1st stage)
6. Lox/Kerosene/LH2

System Architecture #2
Attributes:

1. 8 F1 Engines
2. 3 Stage Rocket
3. Max payload 460,000 lbs to LEO
4. $300 million per launch
5. 13.9 Million lbs of thrust (1st stage)
6. Lox/Kerosene/LH2

3.4a-1 Trade Matrix of Architectures that passed the Feasibility Screening

FOM's / Alternative Architectures	Budget < 25% of budget Wt: 1		Total thrust < 13 million lbf Wt: 2		Lunar orbit Capabilities Wt: 2		Size < 39.4 feet in diameter Wt: 2	
	U	W	U	W	U	W	U	W
Architecture 1	3 (25%)	3	1 (9,279,050 lbf)	2	9 (Yes)	18	9 (33 feet)	18
Architecture 2	1 (30%)	1	3 (16,012,000 lbf)	6	9 (Yes)	18	1 (39 feet)	2

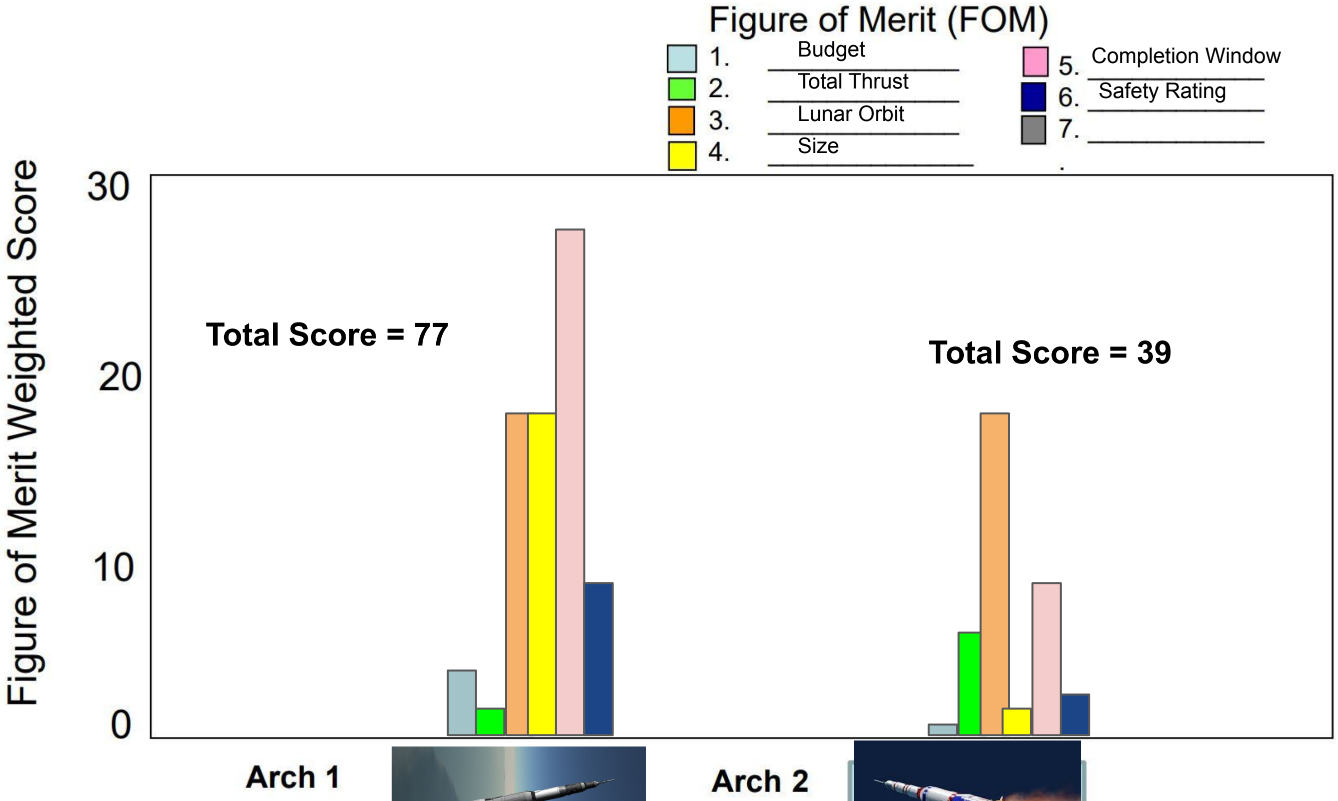
Architecture 1 has a weighted total that is 14 more than architecture 2's so far. It seems like architecture 1 will better suit and meet our FOM's.

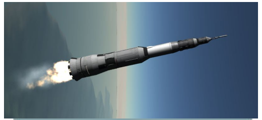
3.4a-2 Trade Matrix of Architectures that passed the Feasibility Screening

FOM's / Alternative Architectures	Completion Window < 9 years Wt: 3		Safety Rating < 10 Rocket Engines Wt: 3		Weighted Total ΣW = Σ (U x Wt)	
	U	W	U	W		
Architecture 1	9 (6)	27	3 (11)	9	77	
Architecture 2	3 (9)	9	1 (17)	3	39	

The weighted total of architecture 1 is bigger than the weighted total of architecture 2. It suits and meets all of our FOM's better than architecture 2.

3.4b Quantify & Down-Selected Alternatives and Order Relative to FOM Scores





Arch. 1 has a greater figure of merit score, meaning it should be our chosen architecture. It features a better budget, smaller build while still achieving lunar orbit with astronauts, and a better safety rating. It is also expected to be completed 3 years sooner.

3.5 Selection of Best Architecture
Saturn C-5

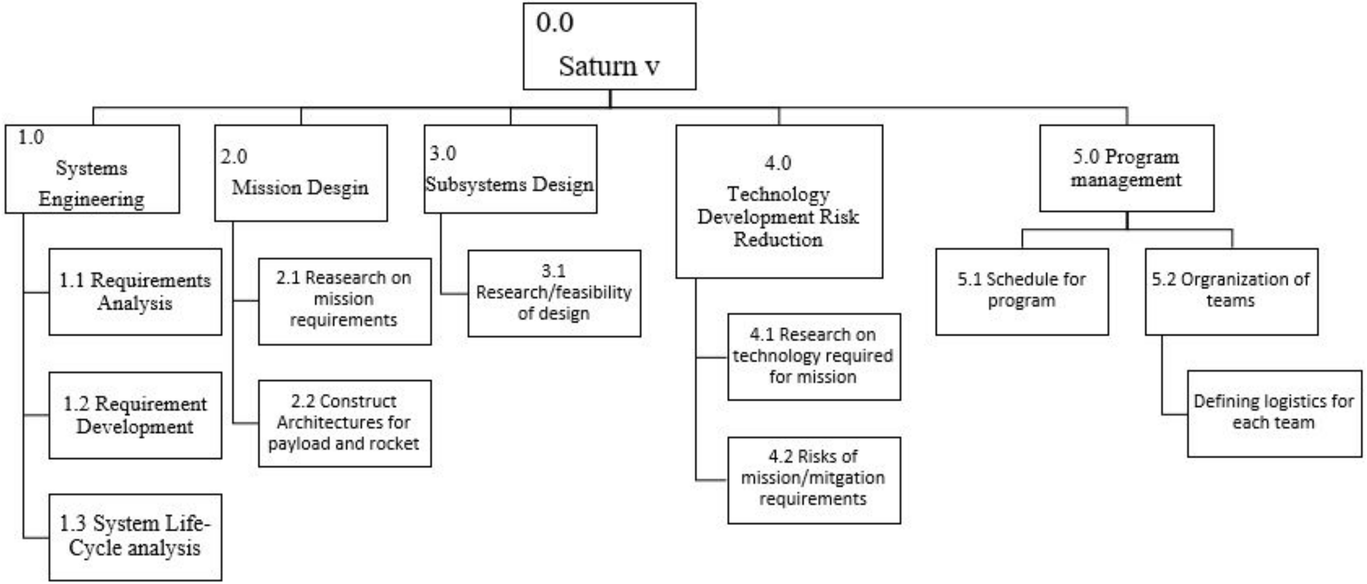
- Selected Architecture & Description:
  Saturn C-5 (3 stages)

  Cost: $185 million per launch
  Wt gross: 5.04 Mlbs
  Wt empty: 287 klbs
  Payload Wt: 52 klbs
  Max payload wt: 320 klbs

- Key Rationale for Selection: The 3-stage Arch 1 design utilizing 5xF1 engines meets the budgetary and launch vehicle size constraints, while capable of entering lunar orbit with a significant margin of safety for the necessary thrust required for the mission.

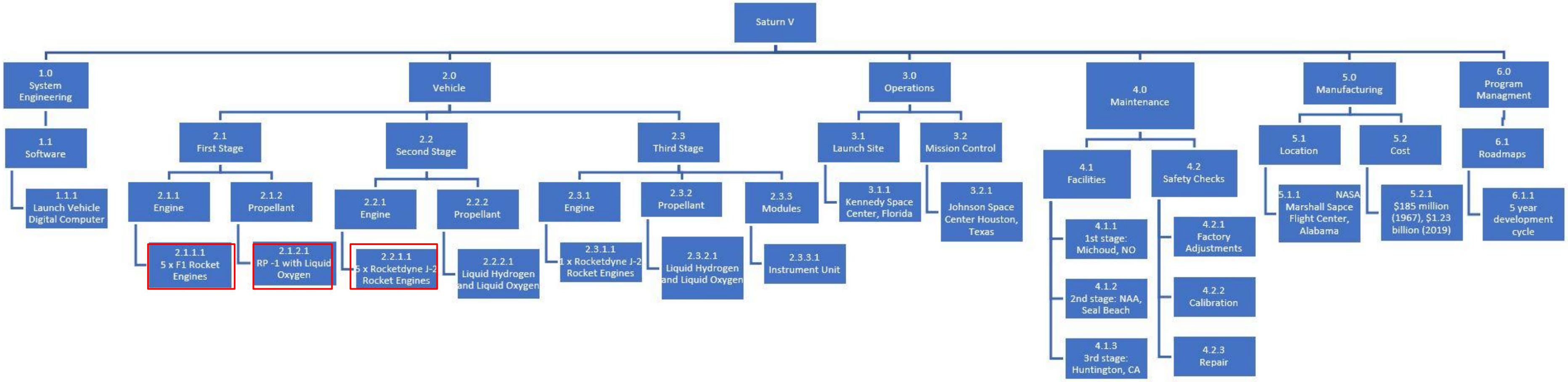
The Arch 1 Saturn C-5 is 61.7% more affordable than the Arch 2 Nova C8, while still meeting the required FOMs and structural parameters with a significant margin of safety for the necessary thrust.

4.0a Functional Work Breakdown Structure



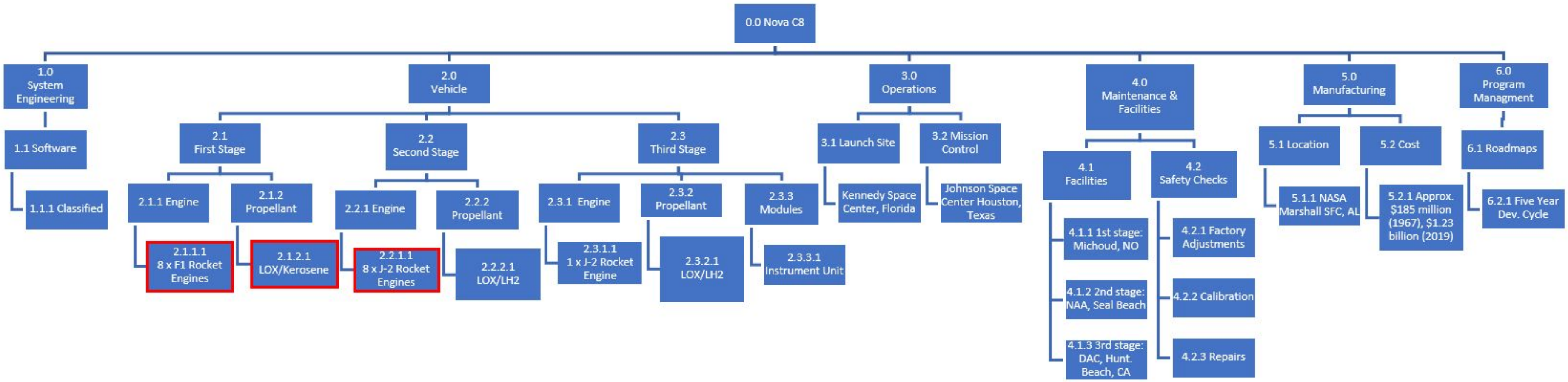
The functional WBS for our systems will provide the most effective layout to design/build/test and manufacture the system for our clients.

4.0b Product Work Breakdown Structure Arch #1



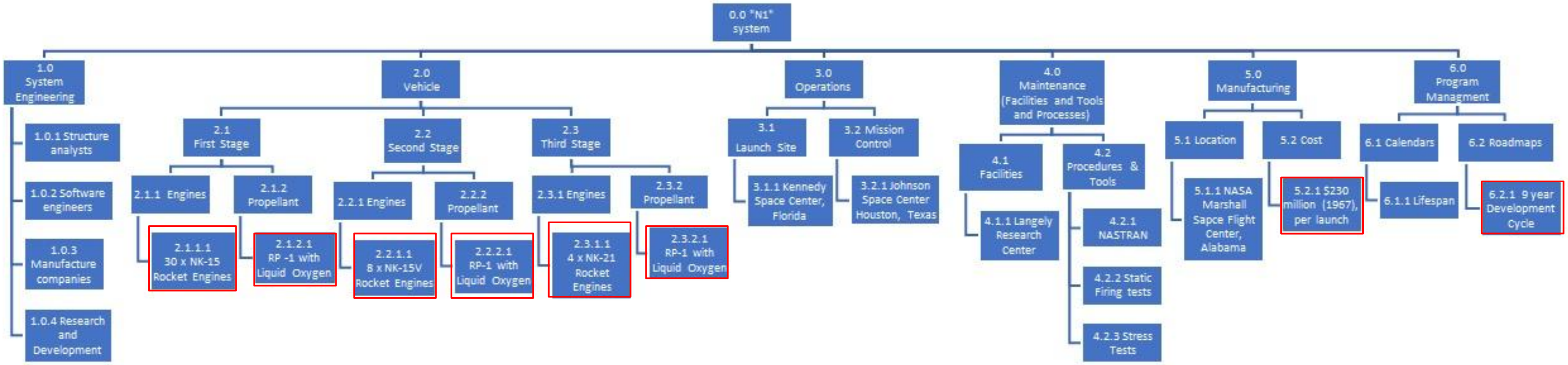
This design architecture will use a three stage design similar to architecture 2. The first and second stages will use a different engine setup, aiding the delivery of the payload.

4.0b Product Work Breakdown Structure Arch #2



The 3-stage Nova C8 design architecture can be scaled up to achieve the mission requirement of transporting a manned crew to the surface of the Moon.

4.0b Product Work Breakdown Structure Arch #3

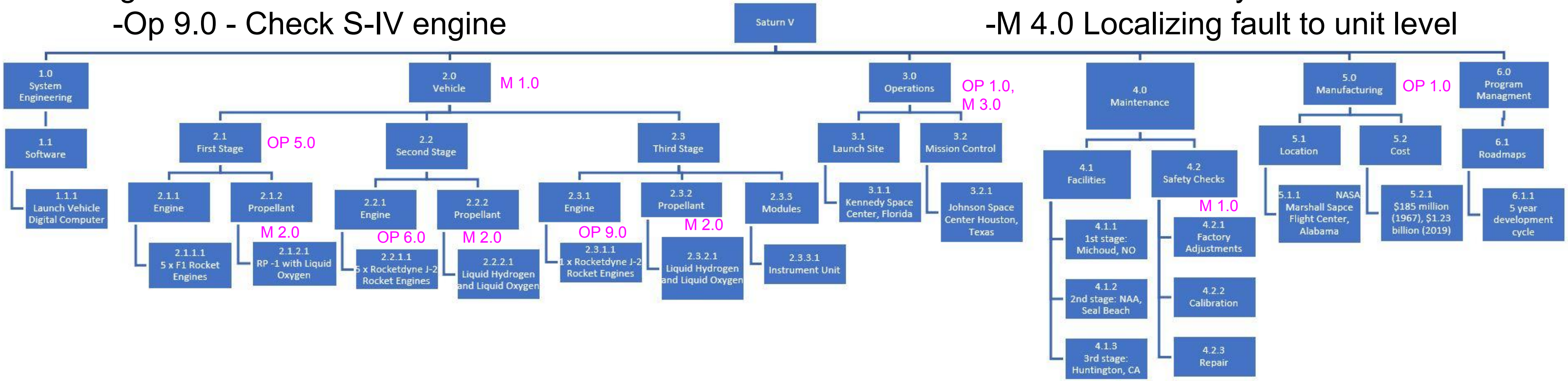


The N1 system has additional engines and a 9 year development cycle with a costly amount per launch.

4.0c Functional allocation on the Product Work Breakdown Structure

Key operations functions
-Op 1.0 - Full systems check
-Op 5.0 - Reach Max Q at 79s
-Op 6.0 - Check S-2C prepare for ignition
-Op 9.0 - Check S-IV engine

Key Maintenance functions (4 required)
-M 1.0 Full systems check
-M 2.0 Propellant check
-M 3.0 Electrical system check
-M 4.0 Localizing fault to unit level



Each major stage is checked prior to moving forward to ensure the flight has no unexpected issues.

5.1-1a Design Reference Mission #1: Apollo 7

What is the system to accomplish?

- Apollo 7 - The Saturn V will launch the payload, specifically a crewed Command Service Module, into LEO

How will the system accomplish its objectives?

- The Saturn V will use 1 F-1 engines on it's 1st stage, 5 J-2 Engines on the second stage, and one J-2 Engine on it’s 3rd stage to get the CSM to LEO

Mission defining Scenario

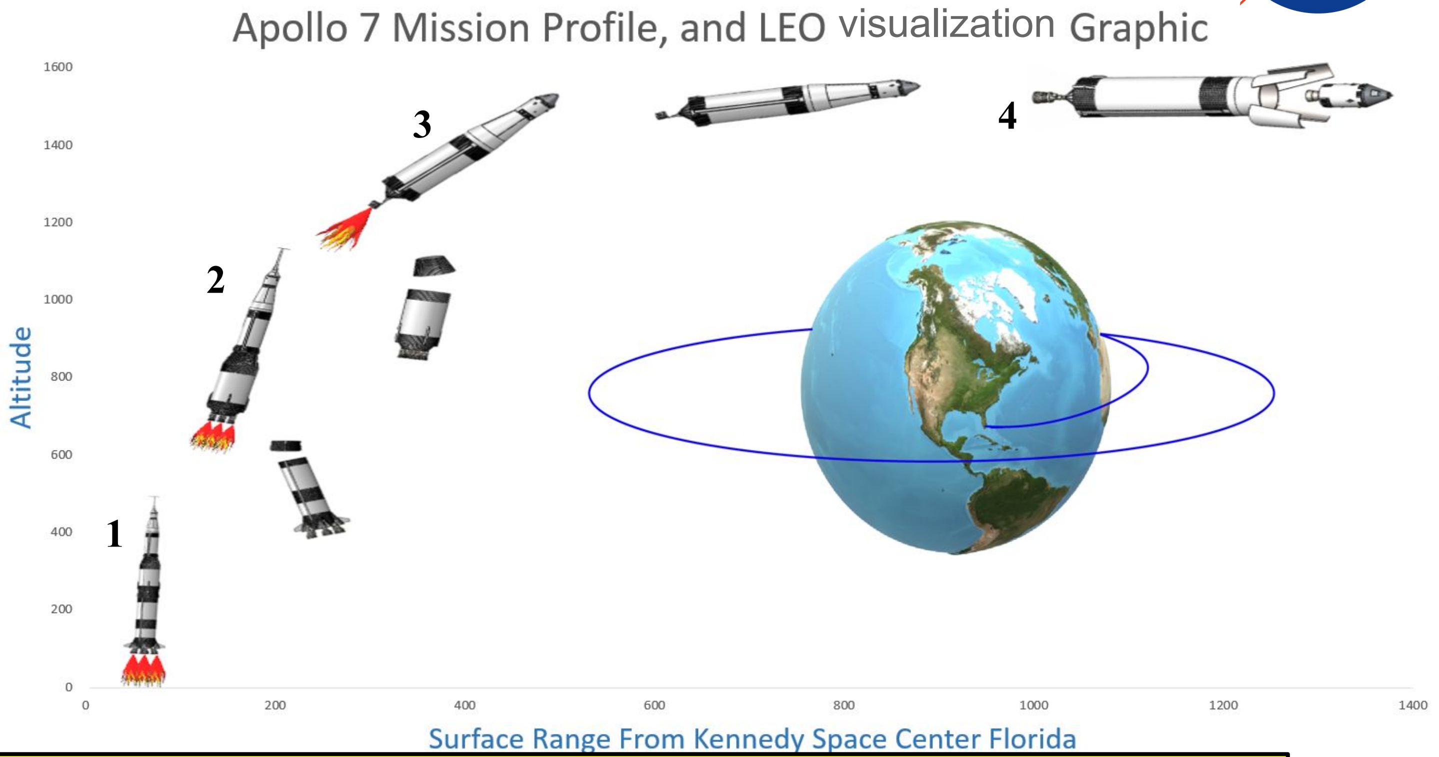
- Scenario #1 First step in re-establishing global dominance and defeating the russians in the space race
- Scenario #2 Saturn V can be used to transport a large payload (310,000 lbs) into LEO

Dynamics of system operating characteristics.

(1.)The Saturn V S-IC 7.5 million lbs of thrust will get the rocket to an altitude of ~46 miles and then cuts off and seperate. At (2.). S-II 1.5 million lbs of thrust takes the rocket out of atmosphere to an altitude of ~100mi and then cuts off and separates.- at this point the LEV ejects (3.) The S-IVB will then boost the rocket to it's LEO insertion point (4) The Payload (CSM) then separates and stays in LEO.

5.1-1b Design Reference Mission #1

1. S-IC ignition, Saturn V launch
2. S-IC Cutoff/ Separation, S-II ignition
3. S-II Cutoff/ Separation, S-IVB ignition enter LEO
4. Payload Separation



The Saturn V will use a three stage design to launch men into orbit, and catch the russians in the Space Race.

5.1-2 Design Reference Mission #2: Apollo 8

What is the system to accomplish

- Apollo 8 - The Saturn V will leave earth's atmosphere. The CSM ,crewed by three men, will orbit the moon, and return safely to the atlantic ocean.

How will the system accomplish its objectives

- The Saturn V will use a multi stage design and a GPO to get the CSM to orbit the moon and return safely

Mission defining Scenario

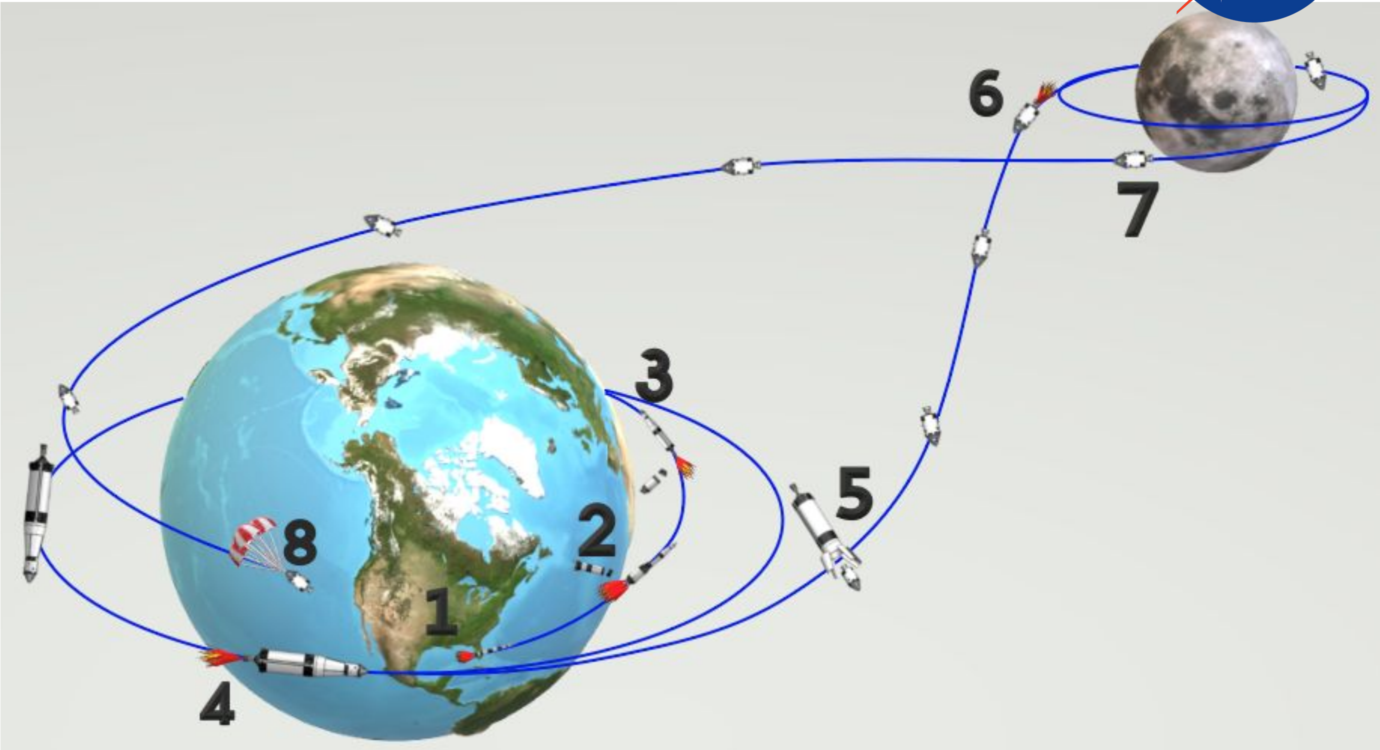
- Scenario #1 Demonstrate global dominance through superiority to russians in space
- Scenario #2 preliminary mission to land on moon to further demonstrate to further demonstrate superiority.

Dynamics of system operating characteristics.

(1.)The Saturn V S-IC 7.5 million lbs of thrust will get the rocket to an altitude of ~46 miles and then cuts off and seperate. At (2.) . S-II 1.5 million lbs of thrust takes the rocket out of atmosphere to an altitude of ~100mi and then cuts off and separates.- at this point the LEV ejects (3.) The S-IVB will then boost the rocket to it's EPO insertion point altitude of 103.4mi (4) S-IVB remains in orbit for 2.5 hours and then restarts to boost for 6 minutes towards the moon. (5.) The CSM then separates and coasts towards the moon(6.) the CSM “de-boosts” using RCS thrust for 12 sec to slow the vehicle get TLI. (7.) the CSM return to earth and (8.) splashdown.

5.1-2b Mission Profile #2: Apollo 8

1. S-IC ignition, Saturn V launch
2. S-IC Cutoff/ Separation, S-II ignition
3. S-II Cutoff/ Separation, S-IVB ignition enter EPO
4. S-IVB 2nd ignition, leave EPO
5. S-IVB Separation from CSM
6. TLI, CSM back boost
7. Escape Moons Orbit
8. Splashdown in the Pacific



The Saturn V will use Earth Parking Orbit (EPO) to complete the first Trans Lunar Insertion (TLI) and beat the Russians in the Space Race

5.2 Performance and Physical Parameters

General Overview

Saturn V size and weight

- Maximum Diameter = 33 ft
- Height = 363 ft
- Gross weight = 6.5 million lb
- Max payload to LE0= 303,000 lbs
- Apollo 8
  Payload weight = 101,000 lbs

Thrust at all stages

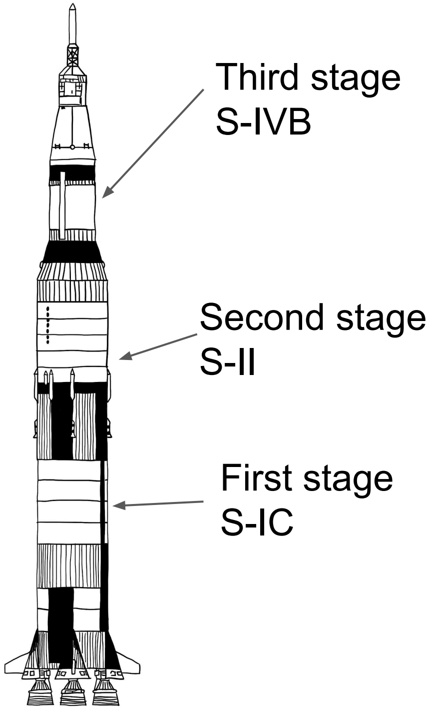
- Total thrust: 9.07 million lbs
- Orbital insertion = 202,600 lbs
- Earth departure = 201,100 lbs

Detailed breakdown

	Stage Dimensions (ft)		Stage Weight (lbs)	
	Diameter	Length	Dry	At Launch
S-IC Base (including fins)	63.0	138.0	288,650	5,022,262
S-IC Mid-Stage	33.0			
Stage - II	33.0	59.3	80,220	1,060,415
Stage - IVB	21.7	59.3	25,050	261,576
Instrument Unit	21.7	3.0	4,306	4,306

Engine Data

Stage	QTY	Engine Model	Nominal Thrust (lbs) Each	Nominal Thrust (lbs) Total	Time (Minutes)
S-IC	5	F-1	1,530,000	7,650,000	2.8
S-II	5	J-2	230,000	1,150,000	6.1
S-IVB	1	J-2	207,000	207,000	1st 2.4 2nd 5.6



The multi stage Saturn V is physically capable of reaching the moon, with a max weight of 6.7 million lbs and a total thrust of 9 million lbs.

5.3a Operational Deployment or Distribution

How much equipment and associated software is distributed, and where is it to be located?

- Three stages produced by separate companies and distributed Total 1 rocket distributed to NASA's Kennedy Space Center in Florida
    - S-IC: Boeing, Michoud, New Orleans
    - S-II: North American Aviation, Seal Beach, CA
    - S-IVB: Douglas, Huntington Beach, CA
- 1 Mobile Launcher at NASA's Kennedy Space Center, consisting of
    - 1 Launch Umbilical Tower
    - 9 swing arms
    - 1 hammerhead crane
    - 1 water suppression system

• 2 crawlers at Kennedy Space Center base, which had to keep the rocket level throughout the 3 mile travel to the launch site. Especially important at the 3 percent grade found near the launch pad.

• 1 Mobile Service Structure

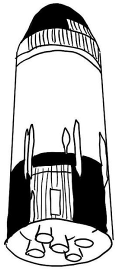
When does the system become fully operational?

• Aircraft #1 fully operational in 1967

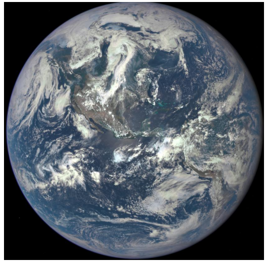
The three stages will be transported to the Vertical Assembly Building at the Kennedy Space Center, which was built for the purpose of storing the assembling the Saturn V.

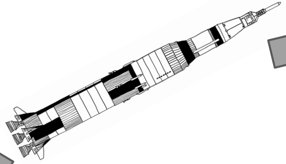
5.3b Operational Deployment Locations

S-IVB maintenance: Huntington, CA



S-II maintenance: Seal Beach, CA





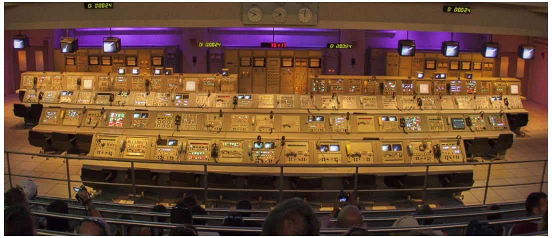
Saturn V

Destination: Moon

S-IC maintenance: Michoud, LA

Mission Control Center:

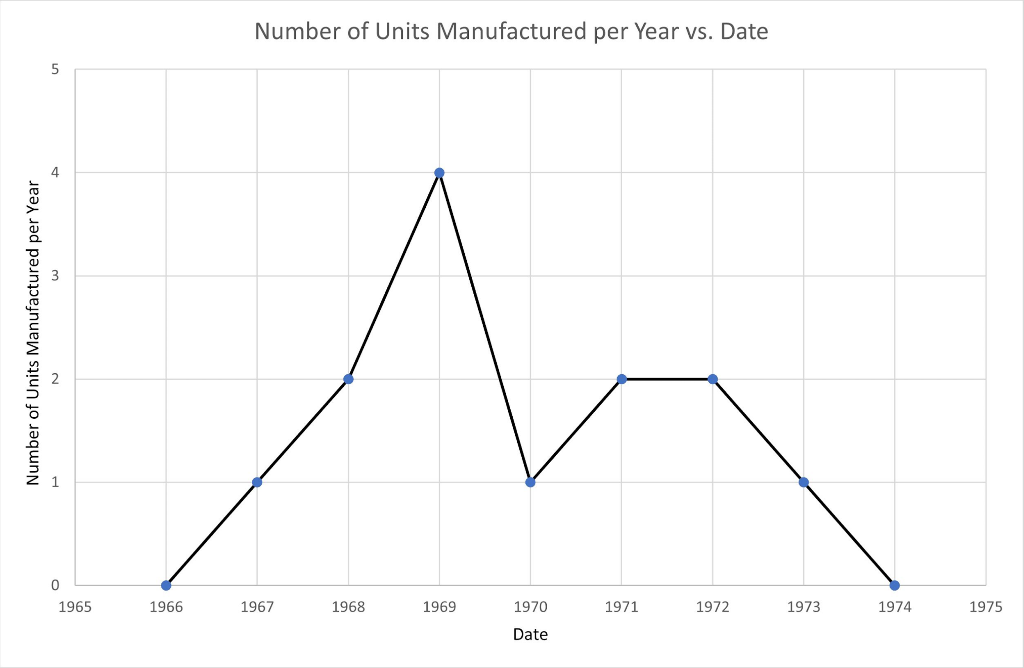
JSC Houston, Texas



Firing room: KSC, Florida

Launch: KSC, Florida

5.4 Operational Life-Cycle



Total number produced over lifetime = 13

NASA will be operating this system for about 7 years.

This system will be produced and launched a total of 13 times. Each rocket cost about $185 million USD (1967) or $1.23 billion USD (2019).

5.5 Utilization Requirements

Anticipated usage of the system and its elements:

- Mission - 1 Launch Vehicle will be in use for 4-5 hours
- Mission - 2 Launch Vehicle in use for 4-5 hours and payload (CSM and Lunar LAnder) will be in use for 6 days
- Both missions
  - S-IC burn time: 2.8 minutes
  - S-II engine burn time: 6.1 minutes
  - S-IVB engine burn time: 2.4 minutes - 2nd burn: 5.8 minutes

How is the system to be used by the customer or operator in the field?

- Mission #1 or Apollo 7 will test the system's capability of launching a minimum payload of 300,000 lbs into orbit (later missions)
- Mission #2 or Apollo 8 will test the systems capability to utilize an Earth Parking Orbit , in order to get a gravity assisted boost and reach Trans Lunar Insertion.

The lunar module will be completely separated from the launch vehicle 4-5 hours after launch. The system is designed for one time use so it will be remade/redesigned for later missions.

5.6 Effectiveness Factors

System effectiveness requirements specified as figures-of-merit (FOM's)

- System must provide enough power/thrust (9 million lbf) for all crew members and payload for orbit safely.
- System must prioritize crew safety with a loss of mission ratio no greater than 1/10,000 for all segments of the mission
- System must be able to track it's own flight parameters with 99% accuracy for all segments of the mission

Given that the system will perform, how effective or efficient is it?

- Detailed rocket engine testing and projections based off of existing engines give us over 9 million lbs of thrust
- Risk analysis of every stage of the saturn V and an abort subsystem projects loss of mission of 1/11,25
- IBM computer calculations which power the IU proven to be accurate enough to track the Saturn V flight parameters

How are these factors related to the mission scenario(s)?

- 9 Million lbf ensures payload will be delivered to the LEO and to the moon
- Guarantees that our astronauts will survive the mission

The system is effective in meeting it's system level requirement figures of merit, Pandora space has the capabilities to complete both mission safely

5.7 Environment

Definition of the environment in which the system is expected to operate:

- Kennedy Space Center, Florida: Temp 40-100 degrees. Humidity: 60%-80%
- Earth's orbit: Temp range -435deg F

How will the system be handled in transit?

- The S-IC and the S-II are to be transported by steamboat and tug boat, in the ocean and the mississippi river.
- The S-IVB is small enough to be flown in on the NASA Pregnant Guppy Airship
- From Vertical Assembly Building, a crawler transporter will move the rocket to the launch site with shock absorbers surrounding the rocket in order to minimize the amount of large vibration

The system will begin in a hot humid Florida at the Kennedy Space Center. A crawler-transporter will move system to launch pad.

6.0 Maintenance & Support Concept Diagram

S-IC: Boeing @ Michaud, NO
S-II: NAA @ Seal Beach, CA
S-IV: Douglas @ Huntington, CA

Major Maintenance (each stage serviced separately at manufacturing location):

Factory adjustments
Complex equipment repair
Detailed calibration
Major Servicing

Minor Maintenance (at the test centers):

Visual Inspection
Minor Servicing
Minor External Adjustments

Transportation:
S-IC: Tug and barge via Mississippi river
S-II: Steamship / tug and barge via Panama canal
S-IV: Air travel via Pregnant Guppy

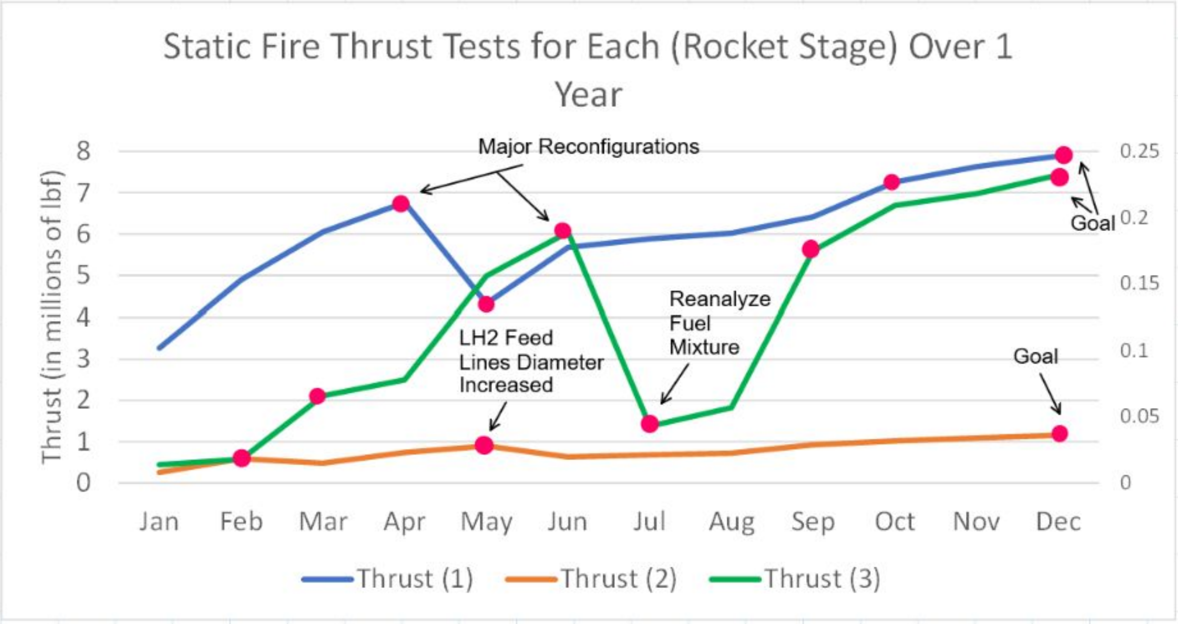
The Saturn V will be primarily maintenanced in stages by each respective stages manufacturer, The 1st two stages will be transported via water, stage three will be transported via air.

7.0a Technical Performance Measures (TPMs) Prioritization

Technical Performance Measure	Quantitative Requirement (Metric)	Current Benchmark (Competing System)	Relative Importance Ranking
Weight	6,200,000 lbs (maximum)	9,964,500 lbs (maximum)	2
Size	270 feet high (launch vehicle) 33 feet wide (maximum)	280 feet high (launch vehicle) 50 feet wide (maximum)	3
Engines	5 F1 engines (first stage) 5 J2 engines (second stage) 1 J2 engine (third stage)	8 F1 engines (first stage) 8 J2 engines (second stage) 1 J2 engine (third stage)	4
Thrust	7,891,000 lbf (first stage) 1,155,800 lbf (second stage) 232,250 lbf (third stage)	13,920,000 lbf (first stage) 1,860,000 lbf (second stage) 232,000 lbf (third stage)	1
Maximum Tracking Radius	100 meters	80 meters	5
New Technology Budget	25% of total budget	30% of total budget	7
Failure Rate to LEO	1/100 flights	1/50 flights	6

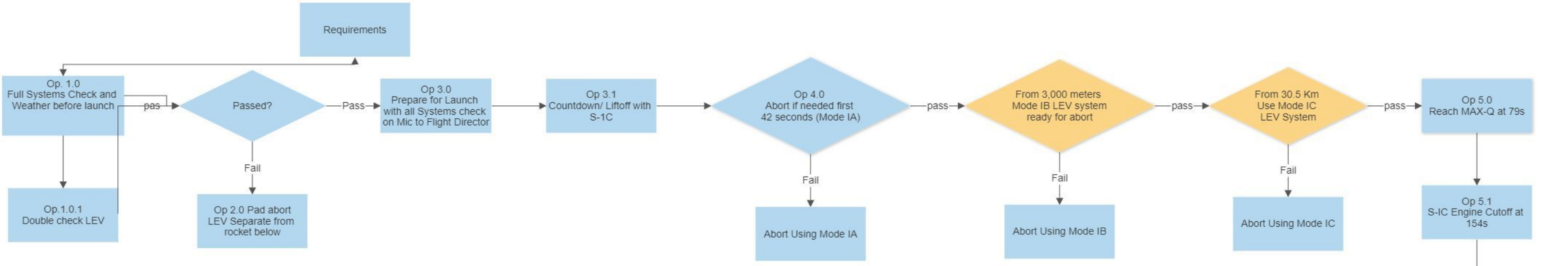
Analysis of the TPMs indicates that the thrust requirement for each stage ranks 1st as the most significant TPM due to the influence of thrust for overall mission success and should be prioritized in all future system designs.

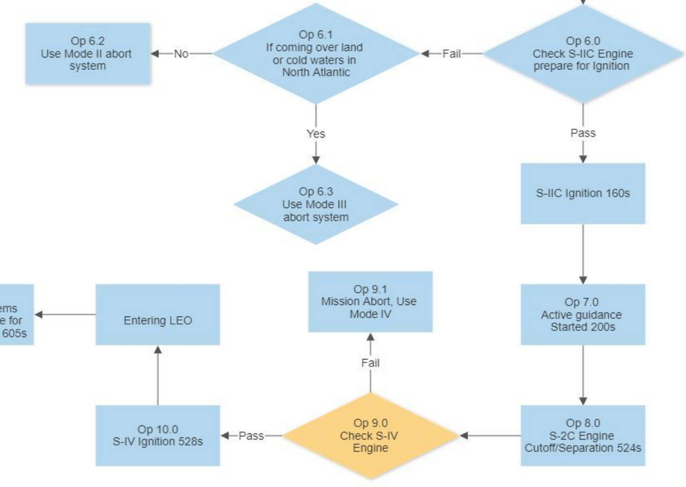
7.0b Desired Thrust for Each Stage. TPM Report Over Conceptual Design Phase & Corrective Actions

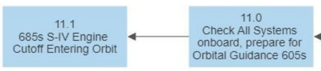


Static fire tests over a series of months indicated that the thrust for each stage was below the desired figures; three engine reconfigurations achieved the thrust goals of 7,891,000 lbf (first stage), 1,155,800 lbf (second stage), and 232,250 lbf (third stage).

8.0a System Functional Flow Breakdown With Requirements Operations- Mission







TR1.1-1: System launch to LEO must have mission fail ration no greater than 1/100

TR1.1-3: System will have a Launch Escape Vehicle (LEV) with mission success of 99.99% in returning crew to earth

TR2.1-1: 3 stage design with 1st stage capable of producing 7,500,000 lbs of thrust to get system out of low earth atmosphere

TR2.3-2: System will have a C-band radar transponder to track the systems trajectory within 100m radius

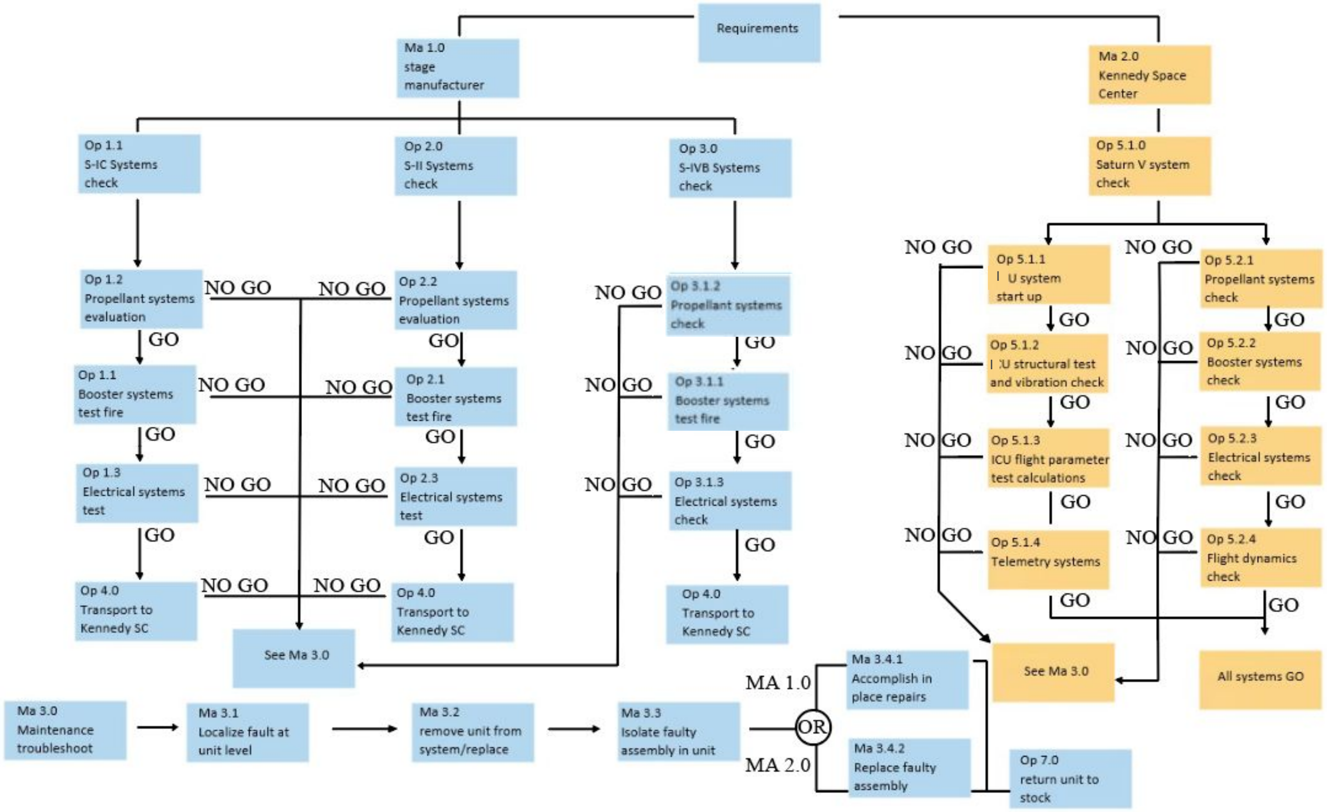
Full system functional breakdown to check all systems before launch ensuring maximum safety and mission success. Using our past experience with delivering the Explorer 1 and Titan I.

8.0b System Functional Flow Breakdown

TR1.1-1: System launch to LEO must have mission fail ration no greater than 1/100

TR1.1-4 each stage of system will be tested and maintained by their respective manufacturers

TR1.1-4.2 The system will be assembled and tested in its entirety at Kennedy Space Center



9. System Spec - Saturn V

1. Design Reference Missions
- 1.1 Apollo 7 Mission
- 1.2 Apollo 8 Mission

2. System Level Requirements
- 2.1 T0.0-1 System must prioritize crew safety with a loss of mission ratio no greater than 1/10,000 for all segments of the mission
- 2.2 T0.0-2 System must have max thrust exceeding 9,000,000 lbs to launch the entire mass of the launch vehicle into space and into orbit.
- 2.3 T0.0-3 System must be capable of Trans Lunar Insertion (TLI) 100km above the lunar surface with safe return to earth
- 2.4 T0.0-4 System must be able to track it's own flight parameters with 99% accuracy for all segments of the mission
- 2.5 T0.0-5 System must be able to be tracked within a 100m radius for all segments of the mission
- 2.6 C0.0-2 System must be able to launch payload for less than $1000 per pound
- 2.7 C0.0-3 Mission must cost less than money allocated for research and development with current NASA budget ($60 billion in 1964)
- 2.8 M0.0-1 System will go from paper to product in less than 9 years in order to launch before end of decade and beat the Russians
- 2.9 M0.0-2 System must weigh less than 7,000,000 lbs in order to be launched at Kennedy Space Center, Florida
- 2.9.1 M0.0-3 System will be launched 15 times, within 7 years In the US

3.Environmental Requirements
- 3.1 Kennedy Space Center
- 3.2 Earth’s orbit
- 3.3 Temp range 0 deg F to 150 deg F
- 3.4 Humidity range 0% to 90%
- 3.5 Crawler-transporters will carry system from assembly building to launch pad at a speed of 1 mph

9. System Spec - Saturn V Cont.

4. Mission & Performance requirements

4.1 Can Carry Large Payload up to 310,000 lbs into LEO
4.2 The S-IC 7.5 million lbs of thrust will get the rocket to an altitude of ~46 miles
4.3 S-II 1.5 million lbs of thrust takes the rocket out of atmosphere to an altitude of ~100mi
4.4 LEV system

5. Utilization and Operational Requirements

5.1 Built at Nasa, MSFC, in Alabama
5.2 Mission Control Center: JSC Houston, Texas
5.3 Launch Site: KSC, Florida
5.4 1 Mobile Launcher at NASA's Kennedy Space Center, consisting of
5.5 1 Launch Umbilical Tower
5.6 9 swing arms
5.7 1 hammerhead crane
5.8 1 water suppression system

6. Maintenance and Support Requirements

6.1 **Engine Stage Maintenance Locations:** S-IC: Boeing @ Michaud, NO, S-II: NAA @ Seal Beach, CA, S-IV: Douglas @ Huntington, CA
6.2 **Major Maintenance** (each stage serviced separately at manufacturing location): Factory adjustments, Complex equipment repair, Detailed calibration, Major Servicing
6.3 **Minor Maintenance (at the test centers)**: Visual Inspection, Minor Servicing, Minor External Adjustments
6.4 **Transportation**: S-IC: Tug and barge via Mississippi river, S-II: Steamship / tug and barge via Panama canal, S-IV: Air travel via Pregnant Guppy

For high mission success rate these are the guidelines and specs of the system we need to follow, failure is not an option during a space race.

10 Conceptual/System Design Review Document Compliance Matrix

Document Section	Compliance? Yes, Partially, No	Author Initials	Page Number
1.1 Needs analysis, 1.2 Goals, 1.3 Objectives;1.4 DRM's; 1.5a System Level Requirements , 1.5b System FOM - Attributes, 1.5c Derived Requirements, 1.6 System Life Cycle x 8	YES	KG(1.1) ,JP (1.5a,1.5b), AP (1.2), RS (1.1, 1.5a, 1.5b) JS (1.6)	3-15
2. Organization Chart – Conceptual design 2a, 2b – Responsibilities. Score x 2	YES	T.L (5.6), RS (2.0, 2.1)	16-17
3. Trade Study: 3.1 Candidate Architectures, 3.2 Sys.Level FOMs 3.3 Feasib. Ana.: Step 4; 3.4a Trade Matrix; 3.4b Quantif. & Down Select (Bar chart) ; 3.5 Select Best Arch. & Rationale statement. Score x 6	YES	KG(3.1,3.2), AP (3.3,3.4), RS (3.5)	18-25
4. Work Breakdown Structure – 4a. Functional, 4b. Product, 4c. Product + Functional Allocations. Score x 3	YES	T.L (4.0a), AP(4.0b1),KG(4.0b 1), RS (4.0b2) JS(4.0b3)	26-30
5. Operational requirements: 5.1 DRMs, 5,2 Perf & Phy Param, 5.3a Ops Deploym, 5.3b Ops Depl Diagram, 5.4 Oper. Life Cycle, 5.5 Utilit. Reqmts, 5.6 Effect. Facts., 5.7 Envirn. Score X 8	YES	JP(5.1,5.5-5.7), AP(5.3,5.4) JS (5,2)	31-41
6. Maintenance & support concept diagram	YES	JP	42
7. Five Tech Performance Measures 7a – Table, 7b – Plot. Score x 2	YES	AP (7.a), RS (7.0a, 7.0b)	43-44
8. Functional block diagrams 8a- Operations, 8b-Maintenance & Support Score x 2	YES	JP(8.0b) T.L (8.0a)	45-46
9. System spec	YES	T.L (9.0)	47-48
10. Compliance Matrix.	YES	JP	49
11. Summary	YES	JS	50

11 Summary

- Key Benefits of chosen Architecture Design Concept
  - With the time it takes to go from paper to first flight taking 6 years, the Saturn V is selected for its quick assembly.
  - This chosen architecture is cost efficient being the least expensive candidate ($185 million per launch).
  - Less engines are required to launch Saturn V towards the moon which means faster production and elevated safety.
- The capability of Pandora Space
  - Our Company was responsible for delivering Explorer 1, America's First satellite in space with the development of Juno I.
  - Our Company designed the Titan I, the first Multistage Intercontinental Ballistic Missile (ICBM) which also used liquid Oxygen and RP-1.
- Questions/Comments/Concerns?

With rapid and cost effective development from design to first flight, the Saturn V is the chosen candidate our company can offer to surpass the Russian Space Program.