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# Simulation Modeling for Space Exploration

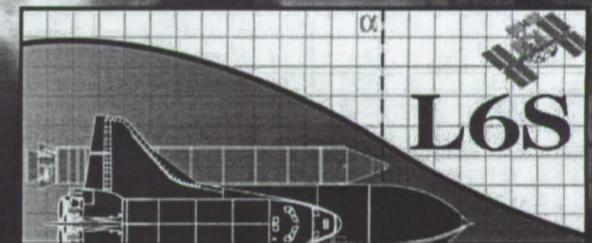
**United Space Alliance, LLC (USA)**

**USA**<sup>®</sup>

*United Space Alliance*

**Dave Tucker**

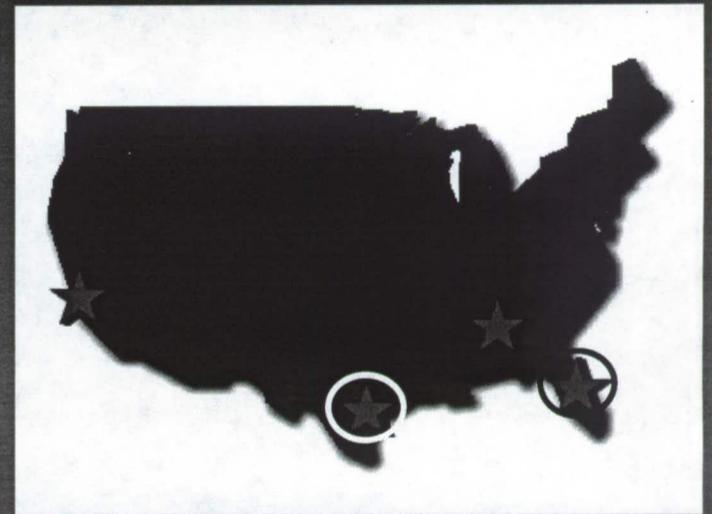
**May 2006**



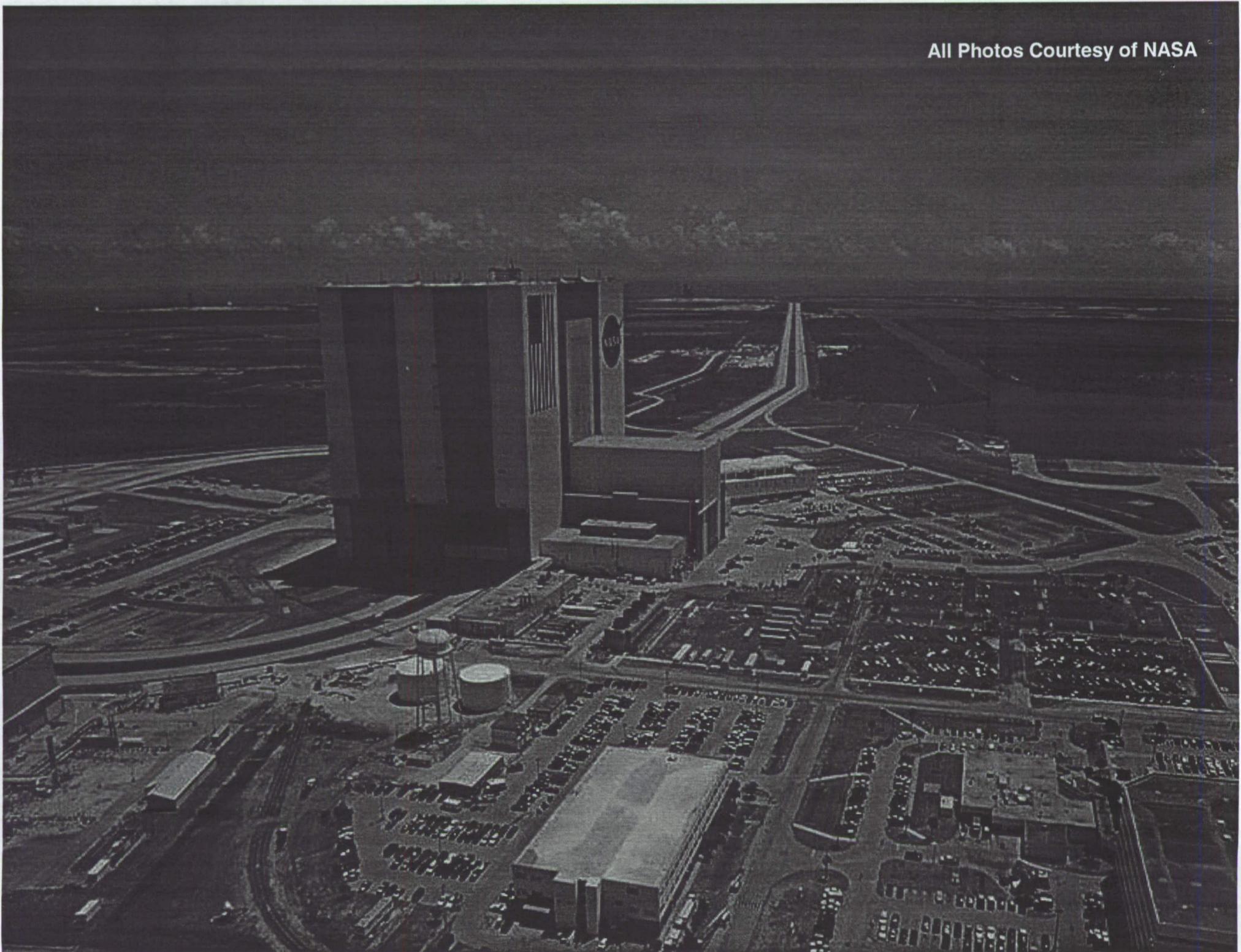
# United Space Alliance (USA)

## Who are we?

- Prime Contractor to NASA for Space Flight Operations Contract
- Responsible for all Space Shuttle Fleet & International Space Station processing operations
- Two primary locations:
  - Johnson Space Center, TX
  - Kennedy Space Center, FL
- About 10,000 employees



All Photos Courtesy of NASA



# United Space Alliance (USA)

## Simulation Experience:

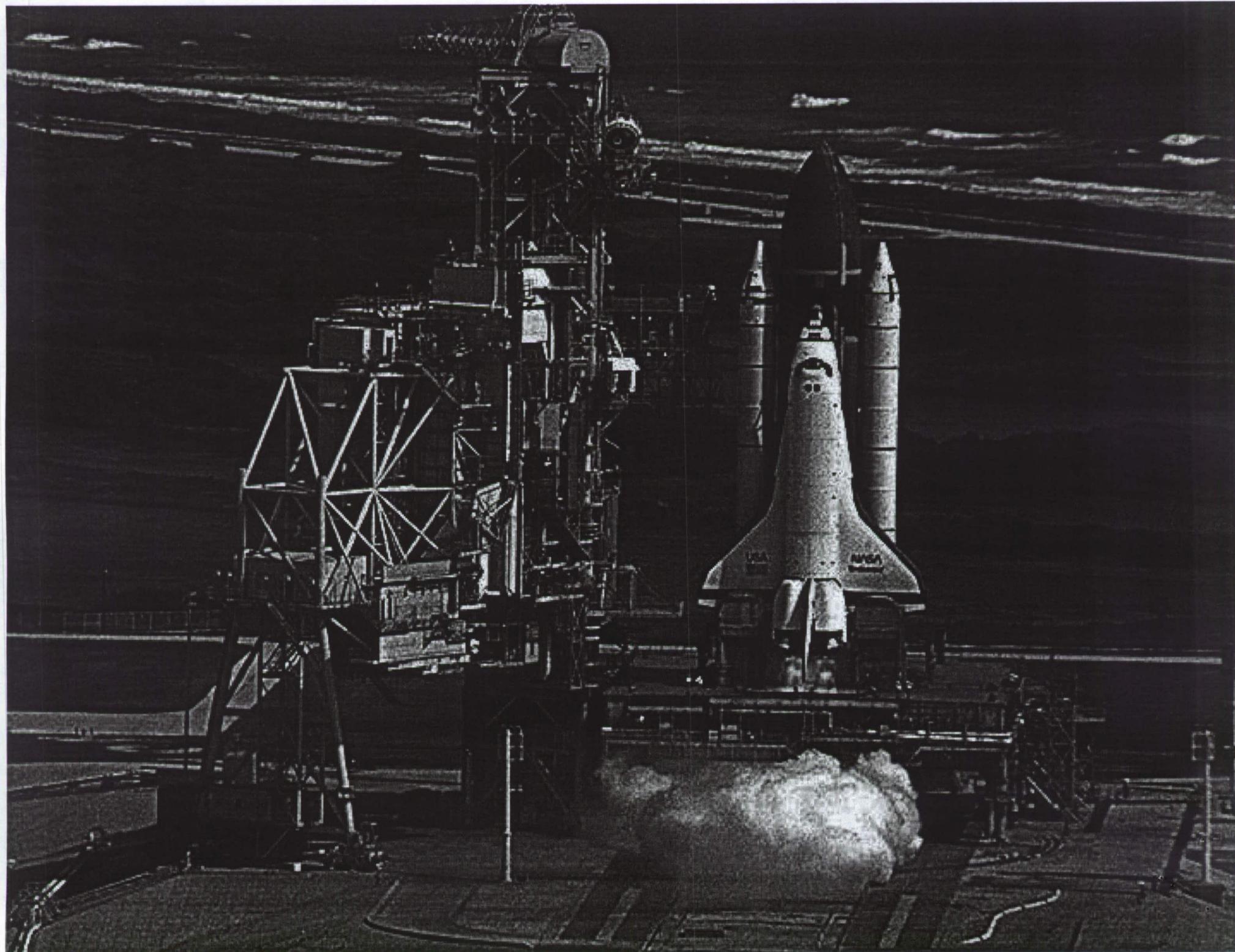
- Six years using ProModel
- Also use PM Process Simulator with Visio
- About three dozen USA employees trained in PM
- Primary ProModel users: IE's, P&M, & other staff
- Completed over two dozen simulation projects
  - Shop Layouts
  - Paper Processes
  - Flight Hardware Processing
  - Manufacturing Operations

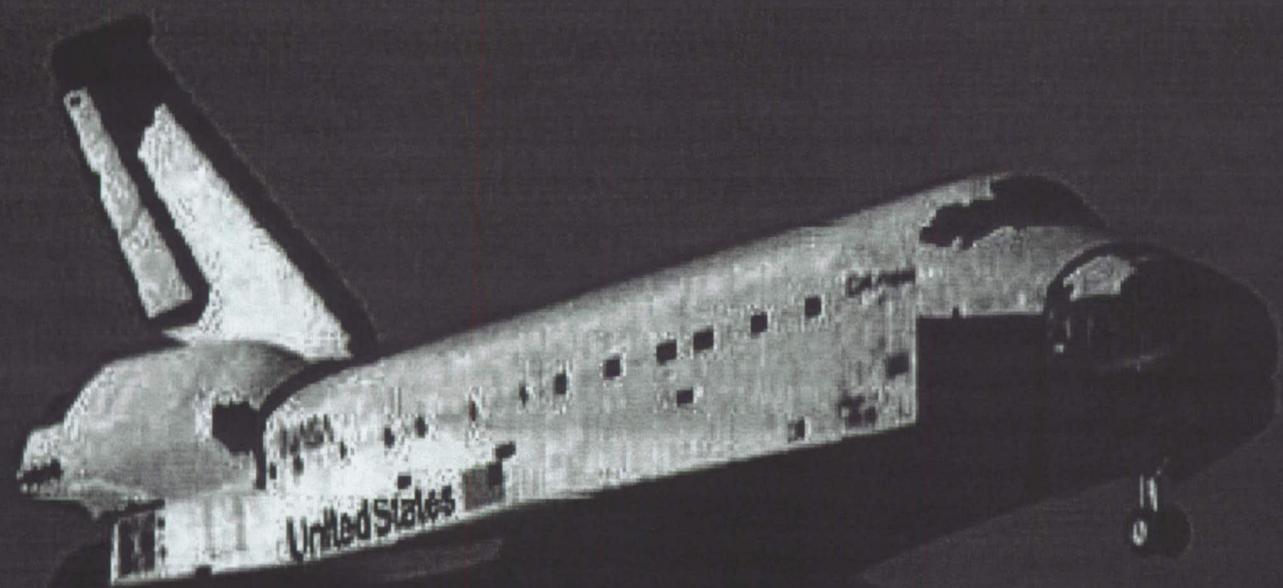


# Today's Shuttle Program

## Space Transportation System:

- Fleet of three Space Shuttle Orbiters
- Solid Rocket Boosters (SRBs) & External Tank (ET)
- Transport crews & cargo to low earth orbit & International Space Station (ISS)
- Orbiters land at Kennedy Space Center in FL or Edwards Air Force Base in CA
- Orbiters & SRBs are refurbished; ET is not
- Flown over 100 Shuttle Missions since 1981

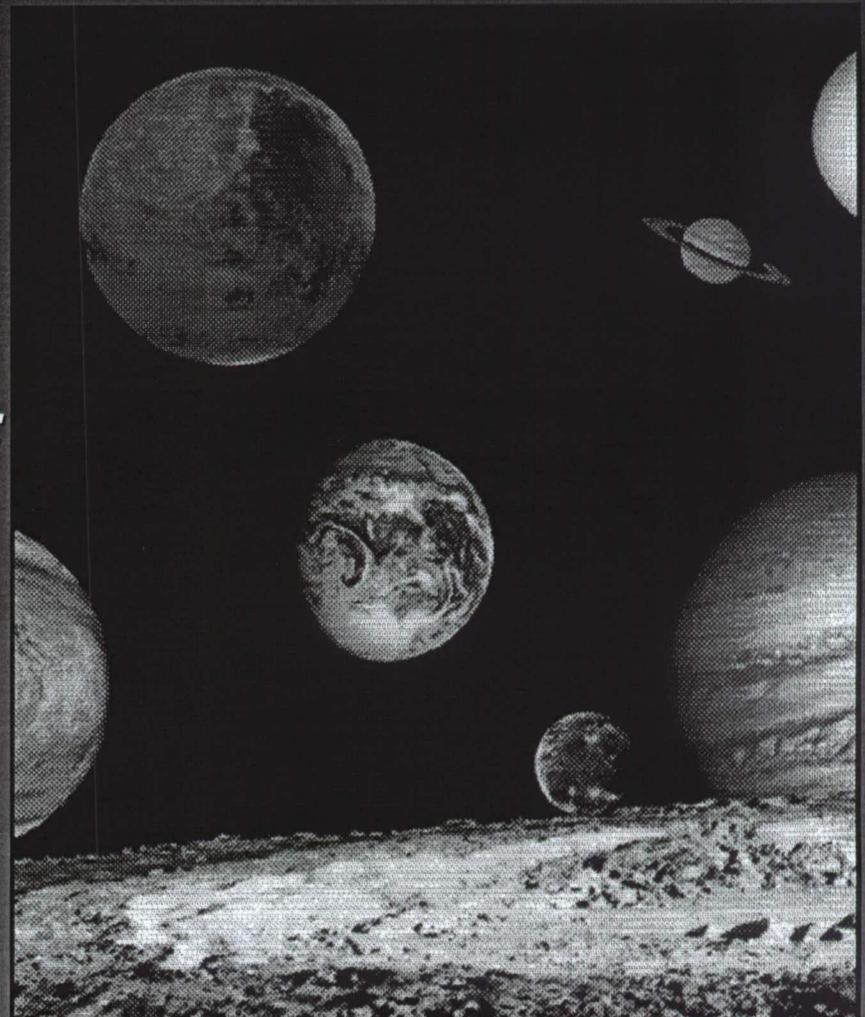




# Tomorrow's Space Program

## Vision for Space Exploration:

*On January 14, 2004, President Bush put NASA on a new course into the cosmos. The Vision for Space Exploration focused the agency on a bold new mission: landing humans on the moon before the end of the next decade, paving the way for eventual journeys to Mars and beyond.*

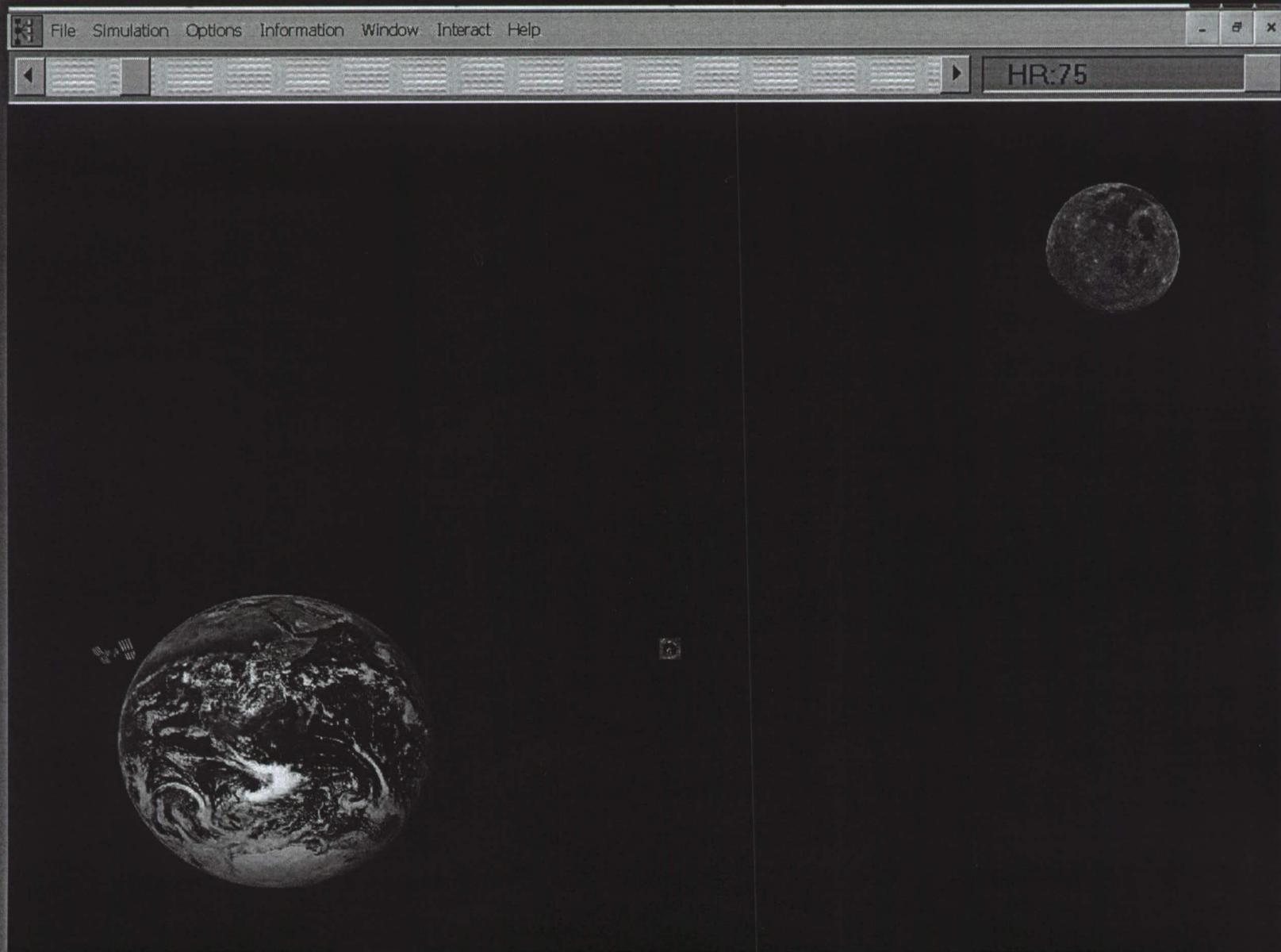


# **Vision for Space Exploration**

## **United Space Alliance:**

- Partnered with several leading companies to develop concepts for space exploration**
- Worked on separate teams**
- Recommendations presented at NASA Headquarters in Washington, D.C.**

# Early Model



# Concepts Explored

## Key Points:

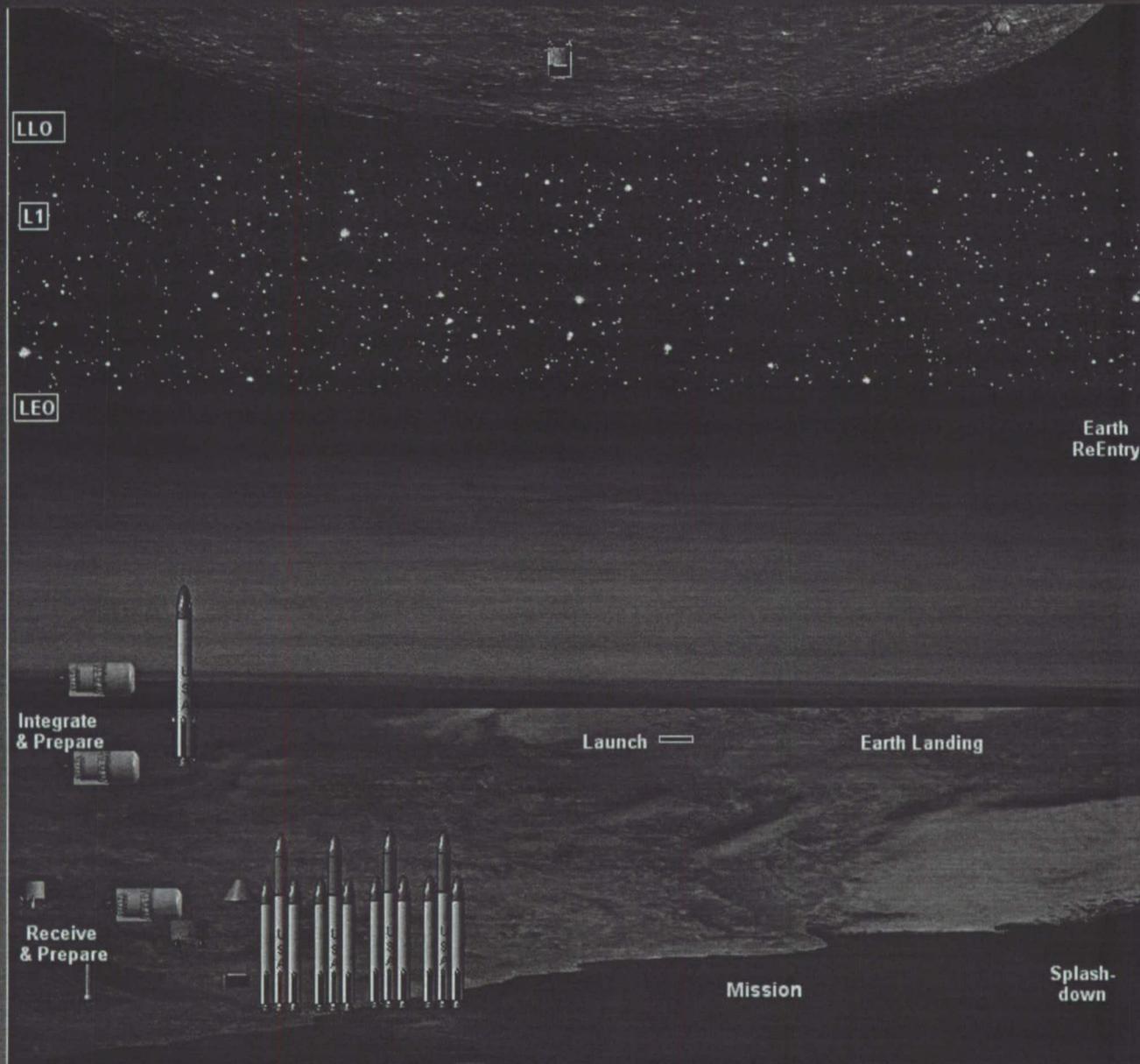
- Missions utilize multiple “single stick” rocket launches to deliver payloads & crew to orbit
- Rockets have different hardware modules onboard depending on mission
- Rockets not reusable; however, some payload modules might be recovered and used again
- Mission progressions must meet NASA timeline milestones

# Exploration Model

## ProModel Simulations:

- Created over a dozen different mission designs
- Built in variability including launch delays, etc.
- One run contains flight manifest sequence of all missions spanning about 20 years
- Created several baseline models
- Performed 100 replications for each study
- Graphics library grew to over 85+ MB

# Exploration Model



# Applications

## Output Results:

- Process Cycle Times
- Mission Sequencing Impacts
- Inventory Requirements
- Reliability Impacts
- Metric Tons Flown
- Crew Days on Moon
- Consumables
- Others

tp 8.5 1-27--.ldb - Output Viewer 3DR - [Report for tp 8.5 1-27-- (

File View Tools Window Help

Views: undefined view

Locations Location States Multi Location States Single/Tank Location Setup Resources

Location States Multi for tp 8.5 1-27-- (Avg. of 28 replications)

Name	Scheduled Time (MIN)	% Empty	% Part Occupied	% Full	% Down
TPSF Entry Q	507930.00	100.00	0.00	0.00	0.00
L110 1	507930.00	92.99	49.02	0.00	0.00
L110 2	507930.00	74.00	28.00	0.00	0.00
L110 2 Stage	507930.00	100.00	0.00	0.00	0.00
L110 3	507930.00	95.18	0.84	0.00	0.00
L110 4	507930.00	90.87	9.13	0.00	0.00
L110 5	507930.00	97.52	2.40	0.00	0.00
L110 6	507930.00	96.29	1.71	0.00	0.00
L110 7	507930.00	33.95	66.05	0.00	0.00
To NCProg Q	507930.00	100.00	0.00	0.00	0.00
L121 1 NCProg	507930.00	71.18	28.82	0.00	0.00

tp 8.5 1-27--.ldb - Output Viewer 3DR - [Report for tp 8.5 1-27-- (Avg. of 20 replications)]

File View Tools Window Help

Views: undefined view

General Locations Location States Multi Location States Single/Tank Resources Resource States Node Entries

Locations for tp 8.5 1-27-- (Avg. of 28 replications)

Name	Scheduled Time (MIN)	Capacity	Total Entries	Avg Time Per Entry (MIN)	Avg Contents	Maximum Contents	Current Contents	Utilization %
TPSF Entry Q	507930.00	999999.00	484.20	0.00	0.00	9.00	0.00	0.00
L110 1	507930.00	999999.00	2472.96	913.28	2.94	22.00	0.15	0.00
L110 2	507930.00	999999.00	14026.46	25.20	0.70	26.50	0.90	0.00
L110 2 Stage	507930.00	999999.00	747.50	0.80	0.80	3.65	0.90	0.00
L110 3	507930.00	999999.00	638.75	5.43	0.91	2.15	0.80	0.00
L110 4	507930.00	999999.00	4067.80	17.23	0.14	10.70	0.85	0.00
L110 5	507930.00	999999.00	2483.25	5.41	0.83	3.65	0.80	0.00
L110 6	507930.00	999999.00	1040.55	5.50	0.92	2.80	0.10	0.00
L110 7	507930.00	999999.00	3072.45	257.29	1.68	23.45	1.30	0.00
To NCProg Q	507930.00	999999.00	0.00	0.00	0.00	0.00	0.00	0.00
L121 1 NCProg	507930.00	999999.00	1613.95	132.19	0.42	8.30	1.85	0.00
L122 1 ODR	507930.00	999999.00	0.00	0.00	0.00	0.00	0.00	0.00
L122 1	507930.00	999999.00	7184.90	131.56	1.94	17.95	1.30	0.00
To CHC Mill Q	507930.00	999999.00	428.60	2.78	0.80	2.80	0.80	0.00
L122 2 CHC Mills 1	506180.00	1.00	1017.60	57.51	0.12	1.00	0.15	11.64
L122 2 CHC Mills 2	506674.00	1.00	294.75	68.94	0.06	1.00	0.06	5.14
L122 2 CHC Mills 3	506671.00	1.00	80.25	108.25	0.02	1.00	0.00	1.74
L122 2 CHC Mills	511823.00	3.00	1792.60	68.93	0.09	3.00	0.20	6.15
To Bandwear Q	507930.00	999999.00	1401.95	129.68	0.84	4.25	0.65	0.00
L122 3 Bandwear	507690.00	1.00	392.65	33.76	0.09	1.00	0.10	4.34
L122 4	507930.00	999999.00	430.56	4.56	0.80	2.50	0.80	0.00
L122 5 PUs	507930.00	999999.00	618.65	2.80	0.80	2.10	0.80	0.00
L122 6 Comp-DR	507930.00	999999.00	0.00	0.00	0.00	0.00	0.00	0.00
To Gunstock Q	507930.00	999999.00	350.20	7.43	0.80	2.90	0.90	0.00
L122 6 Gunstock 1	507750.00	1.00	688.95	78.84	0.10	1.00	0.15	16.31
L122 6 Gunstock 2	507758.00	1.00	290.65	104.64	0.04	1.00	0.05	4.13
L122 6 Gunstock	511658.00	2.00	879.60	84.84	0.07	2.00	0.20	7.22
L122 7 Sand Beach	507930.00	999999.00	1918.80	10.62	0.64	3.05	0.65	0.00
L122 8 Gravel Q	507930.00	999999.00	1.00	7.87	0.00	0.80	0.80	0.00
L122 8 Gravel	507930.00	1.00	67.75	14.88	0.00	1.00	0.80	0.20
L122 Raw Machining	507930.00	999999.00	17.40	0.80	0.80	1.00	0.80	0.00
L123 1 Kaoh Films 1	507574.50	1.00	1027.80	86.94	0.18	1.00	0.35	18.42
L123 1 Kaoh Films 2	507683.50	1.00	334.40	84.10	0.06	1.00	0.20	6.19
L123 1 Kaoh Films 3	507574.50	1.00	71.85	111.11	0.00	1.00	0.05	1.61
L123 1 Kaoh Films 4	507578.00	1.00	20.60	159.38	0.01	1.00	0.80	0.66
L123 1 Kaoh Films 5	507674.50	1.00	8.20	192.33	0.00	1.00	0.80	0.39
L123 1 Kaoh Film	511968.00	6.00	1467.90	47.81	0.60	6.00	0.60	6.64

Notional Data

# Reliability Impacts - Example

## ProModel Simulation Model:

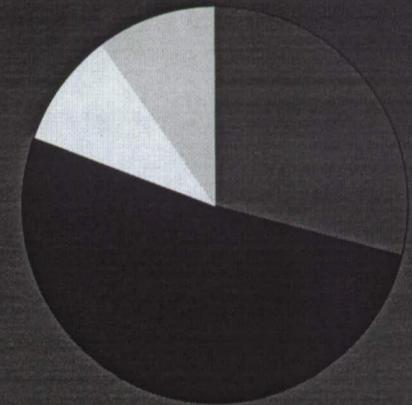
- Inputs an Excel spreadsheet with probabilities that negative events might occur at different stages of a mission, i.e., “probability that a rocket fails to deliver its payload to orbit”
- Model creates an Excel output file recording each event along with mission, rocket, date, location, payload modules on board, etc.
  - Derived Best, Worst, & Average Cases
  - Created a list of hardware needs

# Reliability Impacts - Example

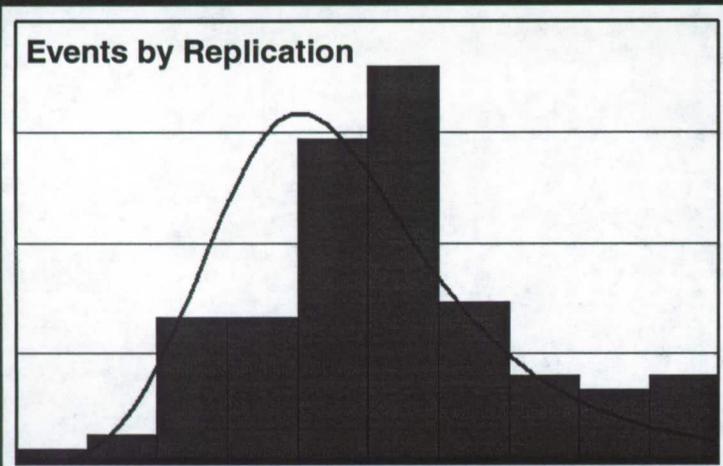
## Notional Data:

Day #	Mission #	1st Entity Element	Launch	Location	RE Type
96.63,	1,	e_ELV_Heavy,	3,	I_Unload_Leo1,	1
1435.92,	4,	e_ELV_Medium,	5,	I_Launch_Pad,	2
1876.59,	5,	e_ELV_Heavy,	3,	I_Unload_Leo1,	1
2120.67,	7,	e_ELV_Medium,	5,	I_Launch_Pad,	3
4814.92,	15,	e_Earth_Departure_Stage,	3,	I_LEO,	5

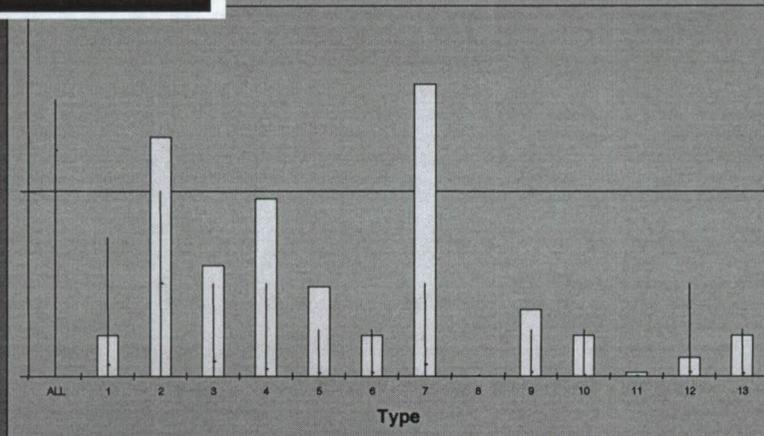
Events by Location



Events by Replication



Events by Type



### Average Spares

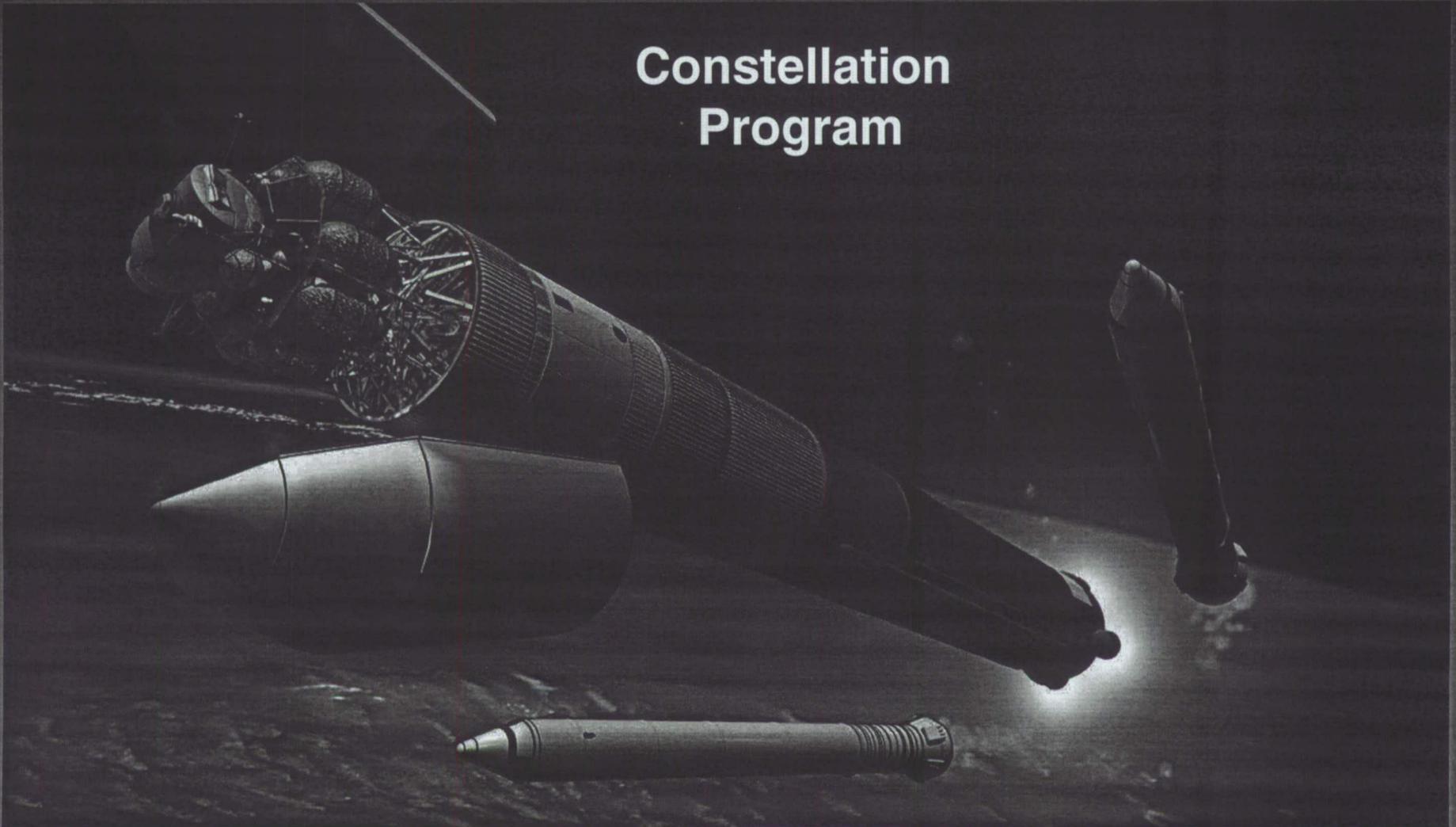
#### Required from Events:

2 ELV-H	1 ELV-M
2 EDS/PEDS	1 Cargo
1 LSAM	2 CM
1 MM	2 SM
1 Hab	

# Concept Defined by NASA

## Shuttle Derived Launch Vehicles (SDLV):

Constellation  
Program

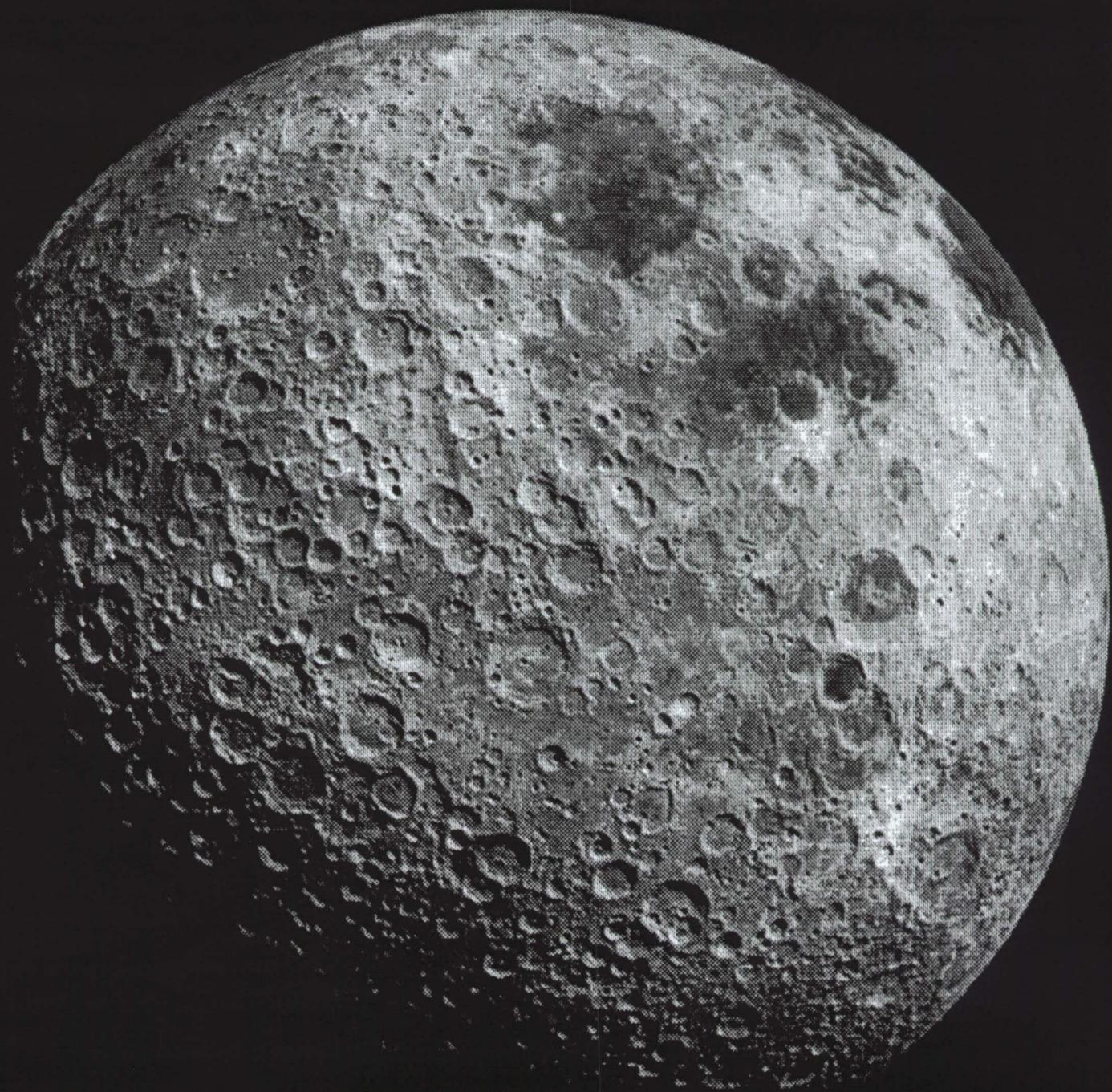


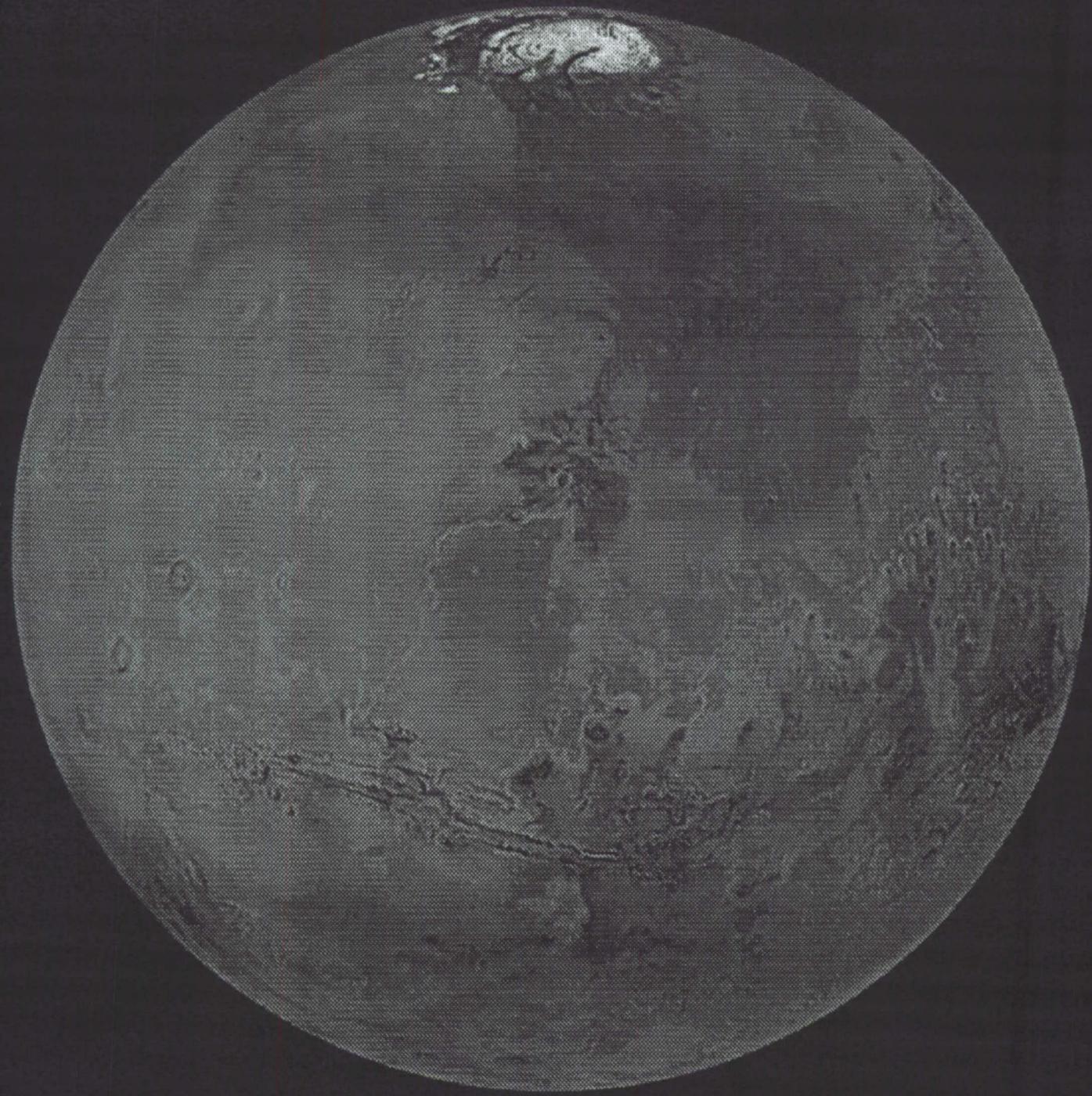
# Next Steps

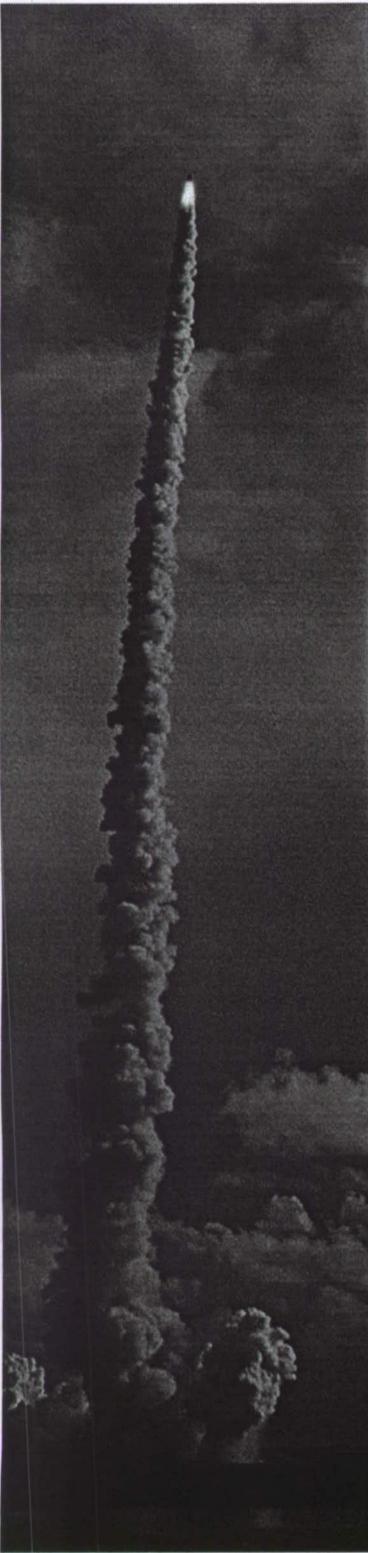
## ProModel Simulation Projects:

- Developing SDLV models
- Opened more opportunities for simulations
  - Expanded M&S interest within USA
  - NASA emphasis on M&S in contracts
- Process simulation continues to be a vital tool in USA's Lean Six Sigma process improvement efforts

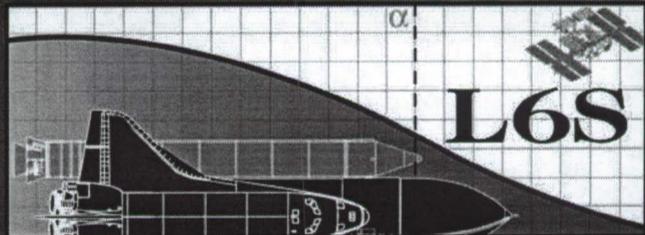








# Thank You





# Best of Hubble Photos

Viewable at <http://hubblesite.org/>  
Or <http://nix.nasa.gov/>











