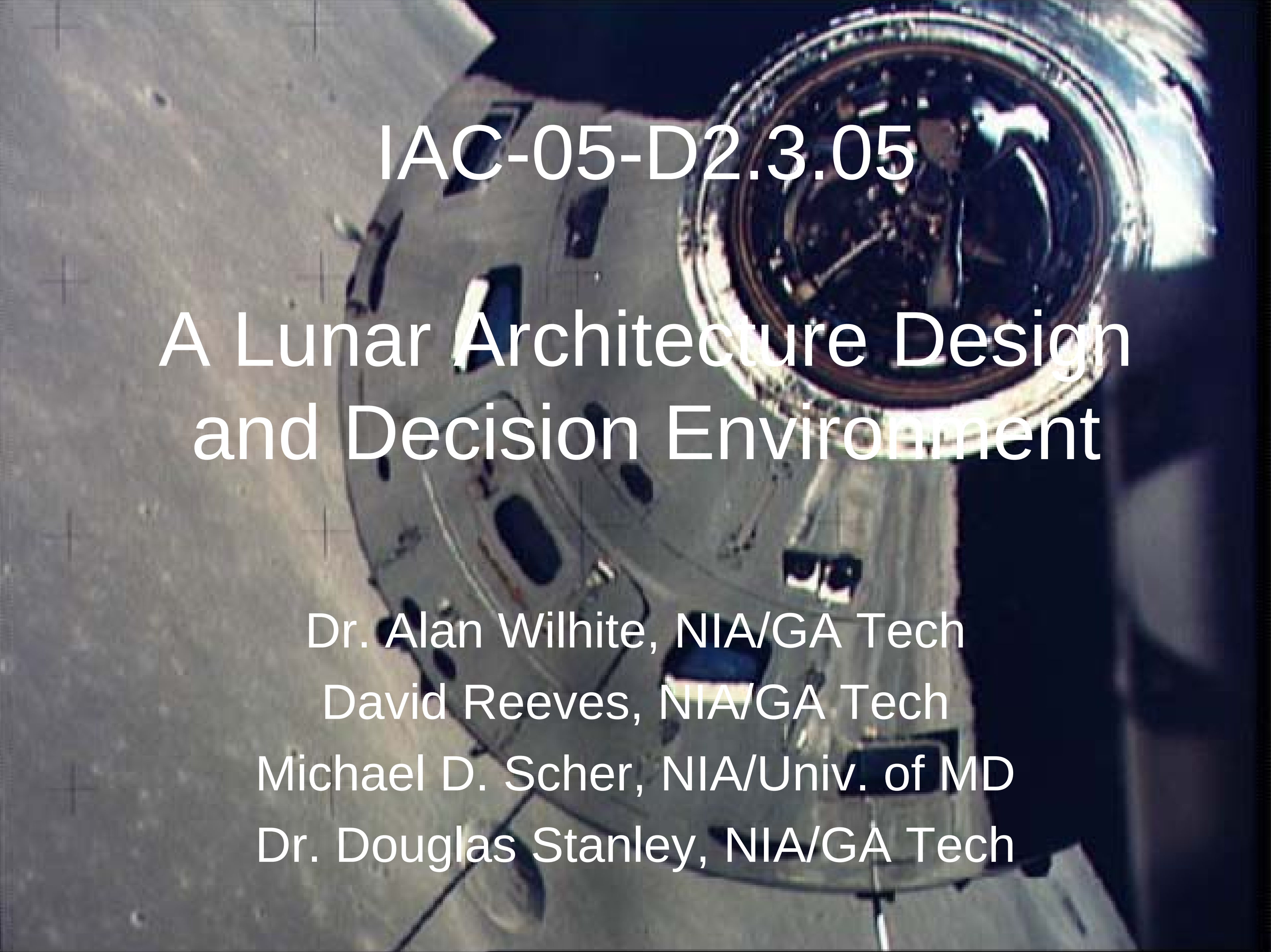

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A Lunar Architecture Design and Decision Environment

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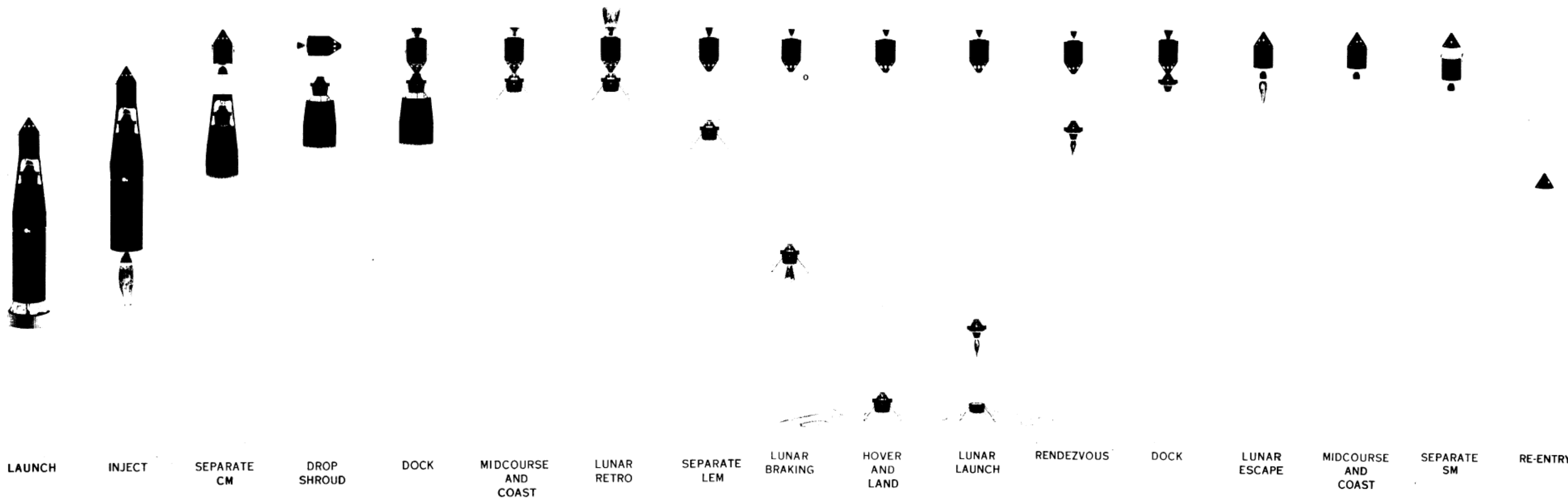
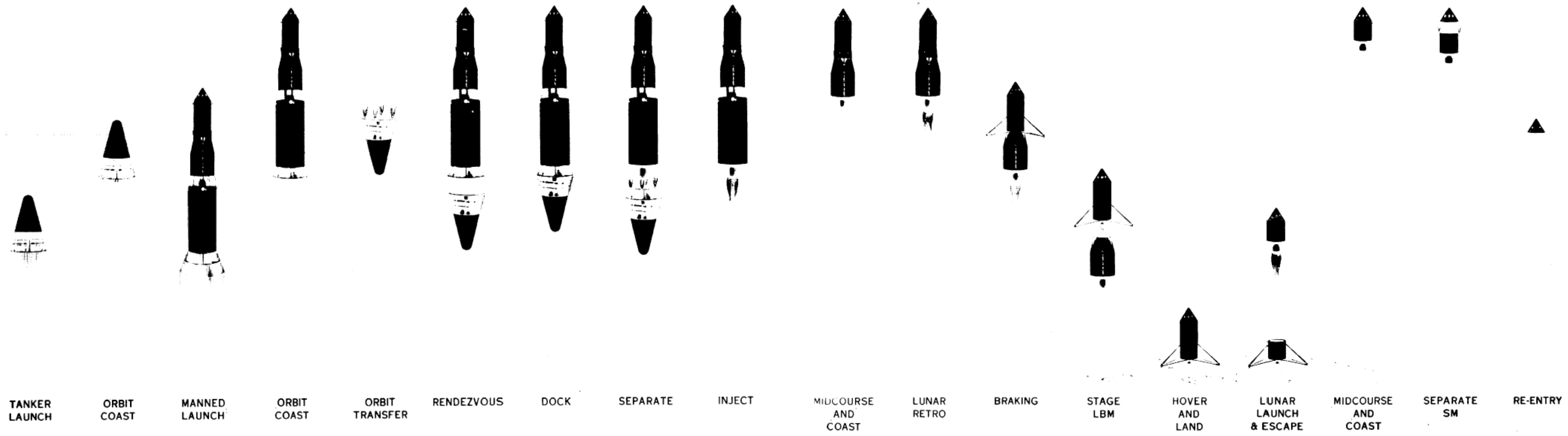
LOR Lunar Mission Mode



National Institute of Aerospace

*From: “Manned Lunar Landing Program Mode Comparison”

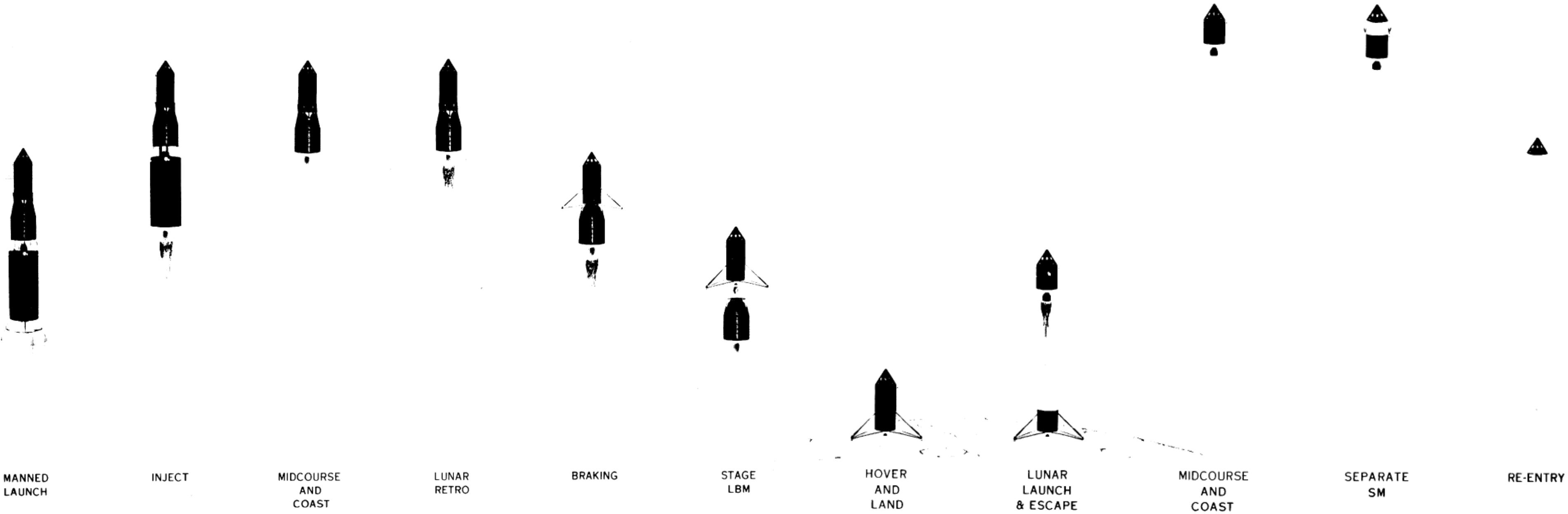
EOR Lunar Mission Mode



National Institute of Aerospace

*From: "Manned Lunar Landing Program Mode Comparison"

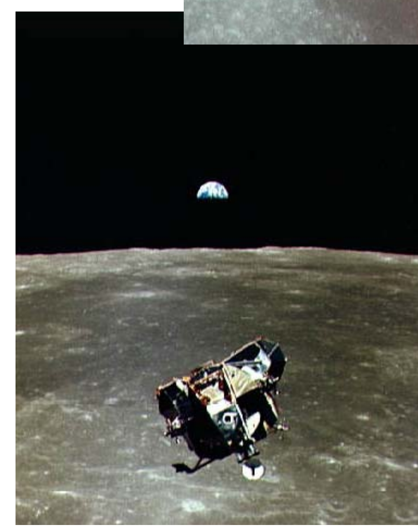
Nova/C-5 Lunar Mission Mode



*From: “Manned Lunar Landing Program Mode Comparison”

Analysis Approach

- The four modes used in the final 1962 decision were analyzed.
- Comparable systems/requirements were used in each mode for an "Apples to Apples" comparison.
- Storable, LOx/LH2, and LOx/CH4 propulsion systems were considered.
- Analysis included cost, mass, reliability, and mass growth sensitivity.
- Current and 1962 weightings were developed for six major FOMs
- Modern decision analysis techniques used to compare results



Modeling Tools

- Mass Modeling
  - Apollo Sizing and Modeling Tool (ASMT)
  - Space Propulsion Sizing Program (SPSP)
- Reliability
  - Qualitative Risk Assessment System (QRAS)
- DDT&E and Production Cost
  - NASA/Air Force Costing Model (NAFCOM)
- Operations Cost
  - Operations Cost Model (OCM)
- Multi-Attribute Decision Making (MADM)
  - Analytical Hierarchy Process (AHP)
  - Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS)

Figures of Merit (FOMs)

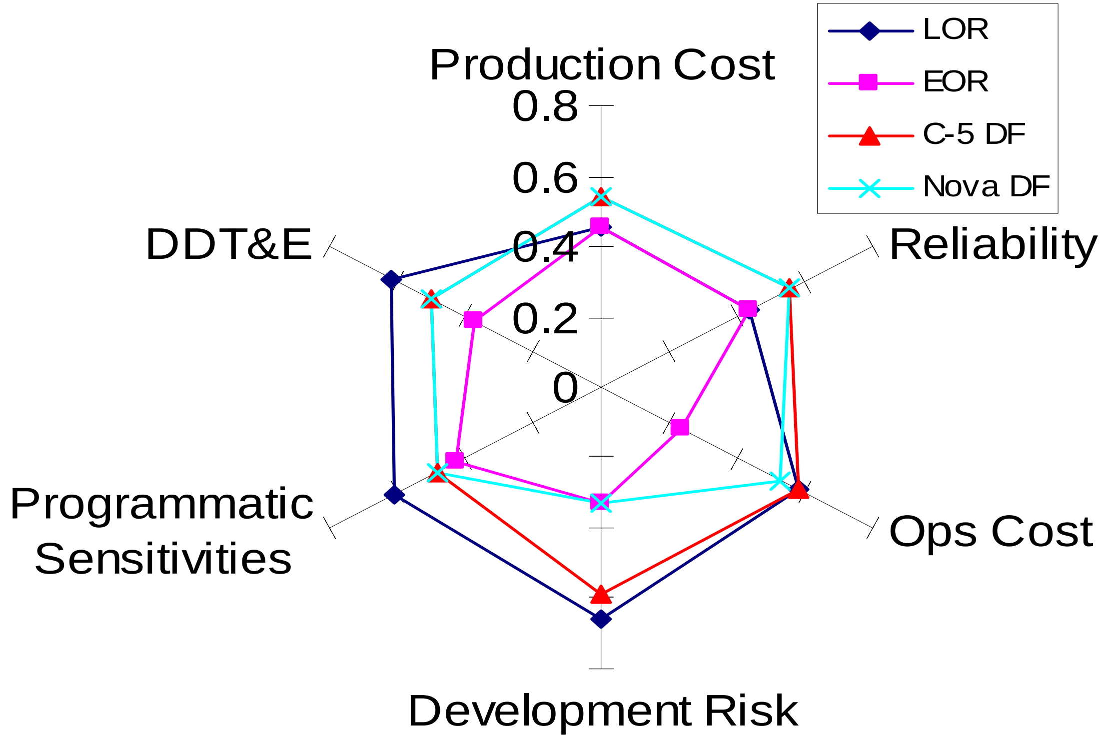
- DDT&E Cost - Cost to design, develop, test, and evaluate all architecture systems to first mission launch.
- Production Cost - Cost per mission to manufacture all required elements.
- Operations Cost - All costs per mission not including production.
- Reliability - Probability of any hardware failure, critical or otherwise.
- Sensitivities - Sensitivity of each element of the architecture to the mass growth of other elements.
- Development Risk – Probability that one or more of the elements will not be developed in the desired timeframe .

FOM Weightings (1962 vs. Modern)

- 1962 mentality:
  - Must meet end of decade programmatic deadline
  - Must be safe and reliable
  - Low development risk is desired
  - Cost is not significant
- Modern Mentality:
  - Timeline is flexible
  - Must be highly safe and reliable
  - Cost is a major driver

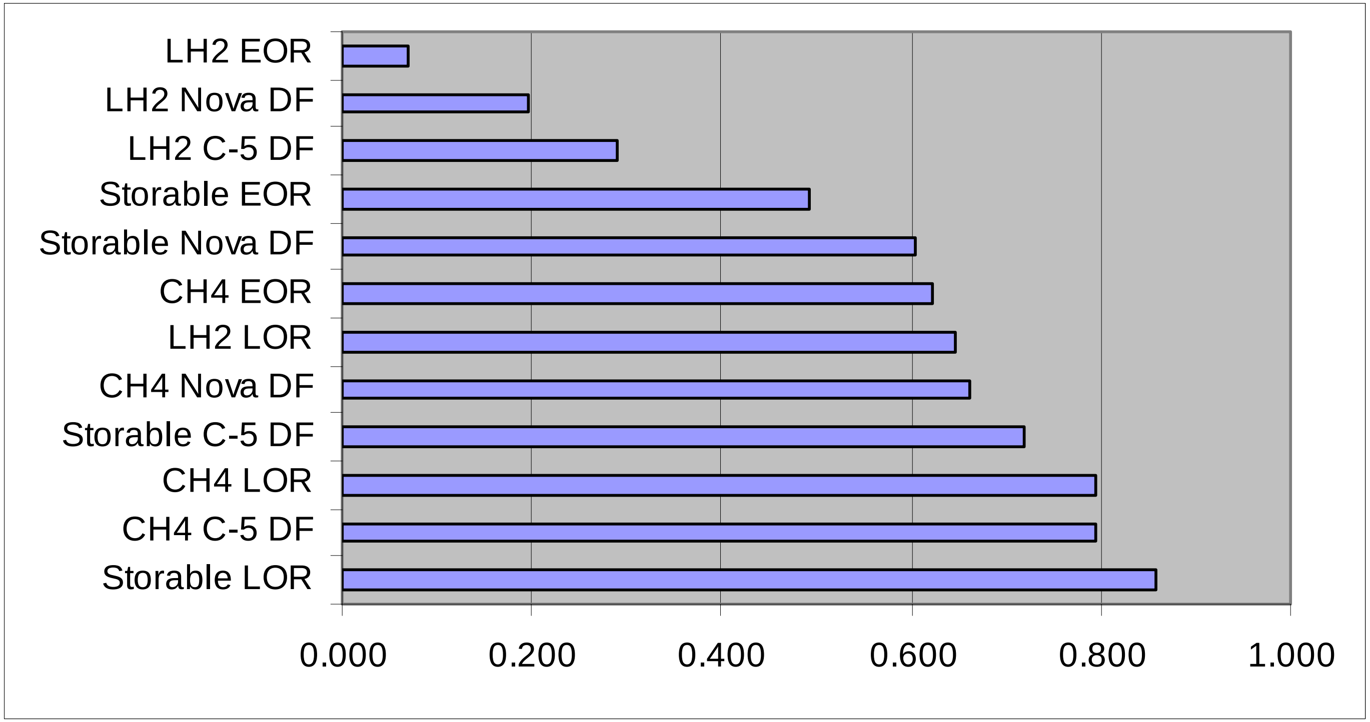
	1962 Weights	Modern Weights
Production Cost	4%	13%
Reliability	20%	33%
Ops Cost	7%	33%
Development Risk	20%	3%
Programmatic Sensitivities	43%	5%
DDT&E	4%	13%

1962 FOM Weighting Results



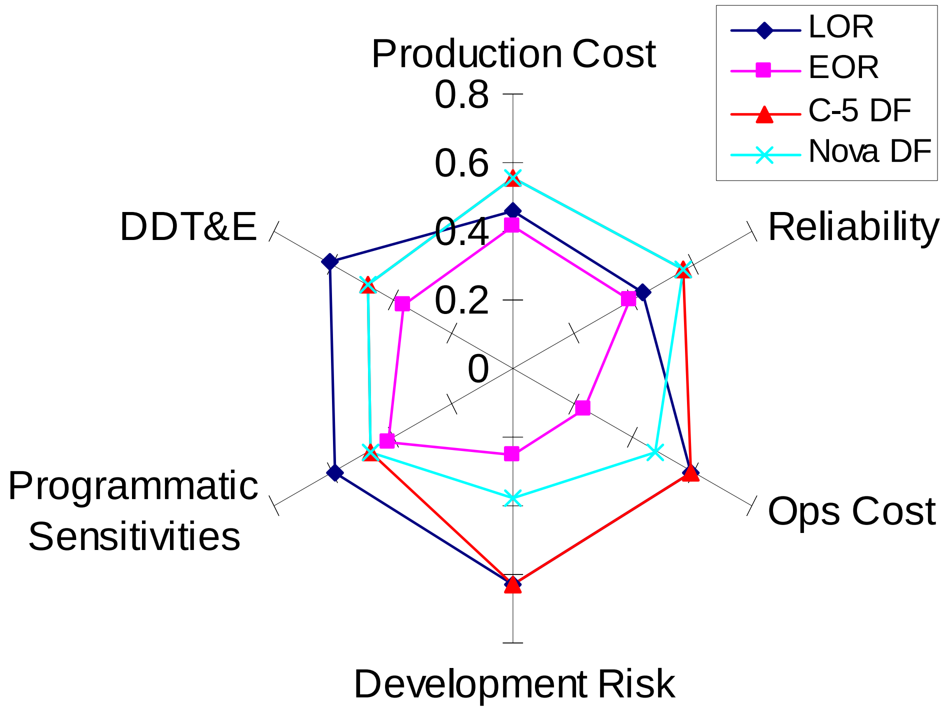
	1962 Architectures	Apples to Apples
LOR	0.80	0.81
C-5 DF	0.56	0.65
Nova DF	0.33	0.34
EOR	0.00	0.00

Comparisons With 1962 Weightings



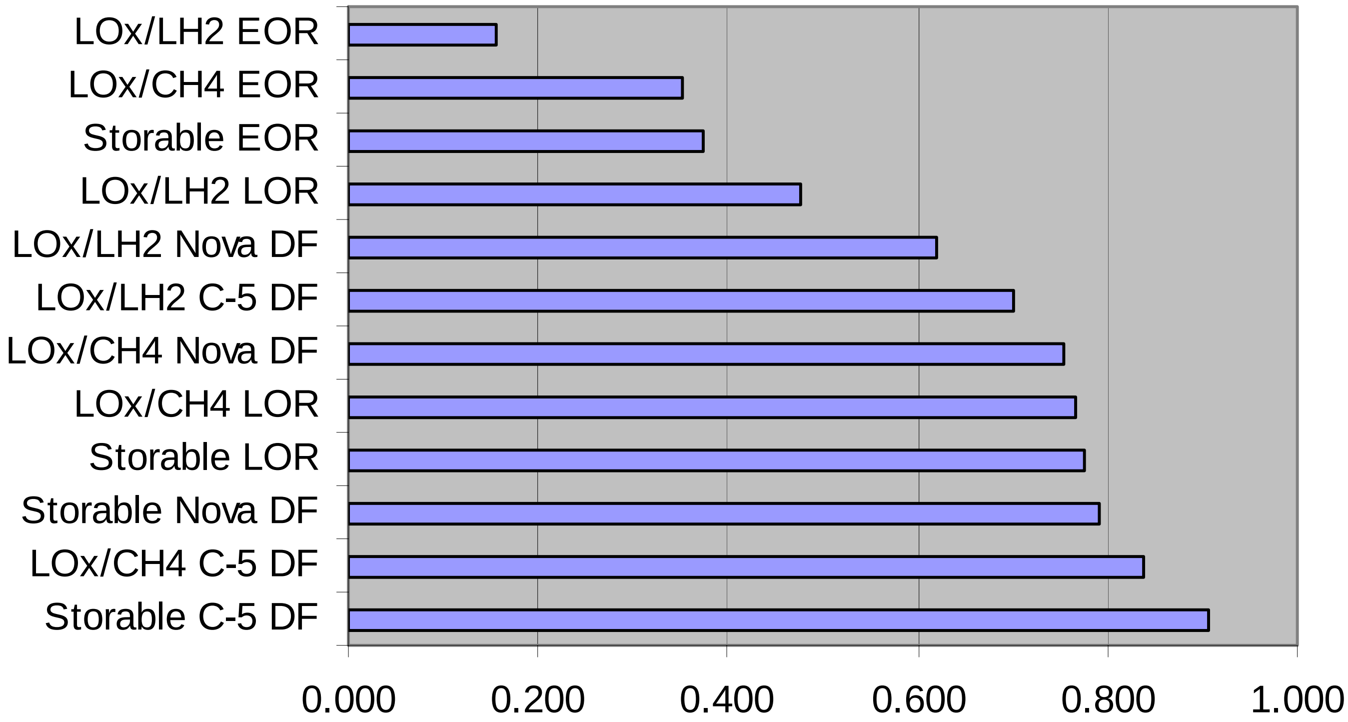
- LOR is least expensive and least sensitive for all propellant types
- C-5 and NOVA Direct modes are most reliable
- EOR ranks last across the board for all propellant types

Modern FOM Weighting Results



	1962 Architectures	Apples to Apples
C-5 DF	0.886	0.891
LOR	0.736	0.734
Nova DF	0.679	0.699
EOR	0.000	0.000

Comparisons With Modern Weightings



- C-5 Direct is favored for modern objectives
  - High reliability
  - Mass and sensitivity reduced by modern technology
  - Schedule and risk not as large a factor
- LOR is still close second place

Summary

- This analysis confirms that LOR was the best option in the 1960's for the Apollo objectives.
- With the modern objectives and constraints, it was found that a single launch direct method becomes more desirable.
- The EOR mode scores lowest in all cases.
- Storable and LOx/CH4 propellants were shown to be somewhat more desirable than LOx/LH2 systems.
- More detailed analysis required to confirm results.

Questions?

Special Thanks to:

- The other Authors – Michael Scher, Alan Wilhite, and Doug Stanley
- Georgia Institute of Technology
- National Institute of Aerospace
- NASA Langley Research Center

1962 Apollo Decision Matrix

	LOR	EOR	Nova DF	C-5 DF
Surface Time	2 days	7 days	7 days	4 days
Surface Access	+/- 20°	global	global	global
Crew to Surface	2	3	3	3
Earliest Landing	Jul-68	Dec-68	Feb-70	Sep-69
Probability of Success	43%	29%	43%	40%
Contracted Elements	4	4	3	2
IMLEO (lbs)	323,173	550,435	445,608	363,478