



**DECISION ANALYSIS WITH THE ANALYTIC HIERARCHY PROCESS AS A
METHODOLOGY TO DEVELOP A MODEL OF SPACE MOBILITY UTILITY**

GRADUATE RESEARCH PAPER

Kristofer T. Fernandez, MS

Major, USAF

AFIT-ENS-MS-22-J-041

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government. This material is declared a work of the United States Government and is not subject to copyright protection in the United States. This report contains fictional representations of future situations/scenarios. Any similarities to real people or events, other than those specifically cited, are unintentional and are for purposes of illustration only. Mention of various programs or technologies throughout this paper does not imply United States Air Force, Department of Defense, or United States Government endorsement of either the mission, the program, or adoption of the technology.

AFIT-ENS-MS-22-J-041

DECISION ANALYSIS WITH THE ANALYTIC HIERARCHY PROCESS AS A
METHODOLOGY TO DEVELOP A MODEL OF SPACE MOBILITY UTILITY

GRADUATE RESEARCH PAPER

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Operations Management

Kristofer T. Fernandez, MS

Major, USAF

May 2022

DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

AFIT-ENS-MS-22-J-041

DECISION ANALYSIS WITH THE ANALYTIC HIERARCHY PROCESS AS A
METHODOLOGY TO DEVELOP A MODEL OF SPACE MOBILITY UTILITY

Kristofer T. Fernandez, MS
Major, USAF

Committee Membership:

Frank W. Ciarallo, PhD
Chair

Abstract

Future warfare with near-peer competitors will require the United States to sustain the Joint Force in a non-permissive, anti-access, and area denial environment, further aggravated by an associated tyranny of distance. Competition in this context highlights a requirement for a strategic lift capability with increased speed and range over current airlift platforms. Rapid advances in commercial rocket technology increasingly make point-to-point terrestrial spacelift, or Rocket Cargo, a leap-ahead capability available to the Combatant Commander. While cost is a factor in selecting a mode of transportation to move, maneuver, and sustain the Joint Force, it is not always the only or most important aspect considered based on military necessity. This research leverages the Global Mobility Enterprise to enable spacelift for point-to-point cargo delivery by applying air mobility-focused Principles of Logistics to space mobility. The Analytic Hierarchy Process as a methodology was utilized to develop a Model of Space Mobility Utility based on decision analysis of identified criteria. The Model and its seven associated factors synthesize the efficacy of two existing airlift platforms and two notional spacelift platforms across the continuum of attainability and responsiveness. The Model of Space Mobility Utility provides future strategists a foundational resource of fundamental Space Mobility Factors to consider when framing the utility of spacelift as a strategic mobility option for the United States.

To my wife and son, whose countless sacrifices I am incredibly grateful.

Acknowledgments

I extend my deepest appreciation to my research advisor, Dr. Frank Ciarallo, for his wise guidance and sincere support throughout the course of this graduate research project. His insights and knowledge were invaluable.

I am appreciative of the staff at the U.S. Joint Chiefs of Staff, Headquarters U.S. Transportation Command and Headquarters Air Mobility Command for being gracious with their limited time in providing the indispensable feedback to strengthen the relevance of this research. Specific thanks to Colonel Jonathan Bland for providing great latitude in sponsoring this work and to Colonel Derek Salmi, Mr. Mark Surina, Lt Col Daniel Magidson, and Maj Gary Olkowski for adding your valued subject matter expertise.

I am grateful to my fellow classmates for making the Advanced Study of Air Mobility (ASAM) a meaningful program to be a part of. I owe a debt of gratitude to the superb leadership and administrative personnel at the USAF Expeditionary Center for the world-class support.

Finally, I am in awe of the visionaries leading the way in developing terrestrial point-to-point cargo delivery via spacelift into a transformative real-world capability.

Maj Kristofer T. Fernandez

Table of Contents

	Page
Abstract	iv
Acknowledgments.....	vi
List of Figures	ix
List of Tables	xiii
List of Equations	xiv
List of Acronyms	xv
 I. Background and Research Problem.....	 1
1.1 Background	1
1.2 Research Problem.....	4
1.3 Research Objectives	4
1.4 Research Focus.....	5
1.5 Investigative Questions	6
1.6 Methodology	6
1.7 Assumptions and Limitations.....	7
1.8 Summary of Findings.....	10
1.9 Implications.....	11
 II. Literature Review	 12
2.1 Global Mobility Enterprise	12
2.2 Commercial Spacelift Industry	18
2.3 Analytic Hierarchy Process.....	25
 III. Methodology	 29
3.1 Analytic Hierarchy Process Flow	29
3.2 Analytic Hierarchy Process Implementation	34
3.3 Analytic Hierarchy Process Criteria.....	34
3.3.1 <i>Responsiveness</i>	36
3.3.2 <i>Simplicity</i>	38
3.3.3 <i>Flexibility</i>	40
3.3.4 <i>Economy</i>	41
3.3.5 <i>Attainability</i>	42
3.3.6 <i>Sustainability</i>	44
3.3.7 <i>Survivability</i>	45
3.4 Analytic Hierarchy Process Alternatives	46

3.5 Analytic Hierarchy Process Network Structure	48
3.6 Analytic Hierarchy Process Alternative Futures.....	50
3.6.1 <i>Alternative Future Indo-Pacific 2030</i>	51
3.6.2 <i>Alternative Future Indo-Pacific 2035</i>	52
3.6.3 <i>Alternative Future Indo-Pacific 2040</i>	53
3.6.4 <i>Alternative Future Europe 2030</i>	54
3.6.5 <i>Alternative Future Europe 2035</i>	55
3.6.6 <i>Alternative Future Europe 2040</i>	56
3.7 Data Description and Analysis.....	58
3.7.1 <i>Alternative Future Indo-Pacific 2030</i>	58
3.7.2 <i>Alternative Future Indo-Pacific 2035</i>	66
3.7.3 <i>Alternative Future Indo-Pacific 2040</i>	74
3.7.4 <i>Alternative Future Europe 2030</i>	82
3.7.5 <i>Alternative Future Europe 2035</i>	90
3.7.6 <i>Alternative Future Europe 2040</i>	98
3.7.7 <i>Summary</i>	106
IV. Analysis and Results.....	107
4.1 Overview	107
4.2 Model of Space Mobility Utility	108
4.3 Results of Multiple-Criteria Decision Analysis	110
4.3.1 <i>Alternative Future Indo-Pacific 2030</i>	112
4.3.2 <i>Alternative Future Indo-Pacific 2035</i>	113
4.3.3 <i>Alternative Future Indo-Pacific 2040</i>	114
4.3.4 <i>Alternative Future Europe 2030</i>	115
4.3.5 <i>Alternative Future Europe 2035</i>	116
4.3.6 <i>Alternative Future Europe 2040</i>	117
4.4 Investigative Questions Answered.....	118
4.5 Summary	121
V. Conclusions and Recommendations	122
5.1 Conclusions of Research.....	122
5.2 Significance of Research.....	122
5.3 Recommendations for Action and Future Research.....	123
Appendix A.....	124
Appendix B	125
Bibliography	128
Vita.....	136

List of Figures

	Page
Figure 1: Point-to-Point Space Transportation Concept of Operations	3
Figure 2: Cost Per Kilogram Rapidly Decreases as Flight Rate Increases	9
Figure 3: Model of Space Mobility Utility	10
Figure 4: Illustration of Lily Pad Operations	14
Figure 5: Illustration of Air Bridge Operations	14
Figure 6: Integrated Basing in the Context of Base Archetypes.....	15
Figure 7: Artist’s Rendering of Rocket Cargo for Agile Global Logistics.....	19
Figure 8: Two SpaceX Falcon Heavy Boosters Landing.....	20
Figure 9: Starship and New Glenn Size Comparison	20
Figure 10: Point-to-Point Space Transportation Capabilities Explored Under the AFRL Rocket Cargo Vanguard Program.....	23
Figure 11: SpaceX Starship Re-Entry Trajectory	40
Figure 12: Model of Air Mobility Utility	43
Figure 13: AHP Hierarchy	49
Figure 14: Alternative Future Indo-Pacific 2030 - OPM (Main Criteria)	58
Figure 15: Alternative Future Indo-Pacific 2030 - OPM (Responsiveness).....	59
Figure 16: Alternative Future Indo-Pacific 2030 - OPM (Survivability)	60
Figure 17: Alternative Future Indo-Pacific 2030 - OPM (Simplicity)	61
Figure 18: Alternative Future Indo-Pacific 2030 - OPM (Flexibility)	62
Figure 19: Alternative Future Indo-Pacific 2030 - OPM (Attainability).....	63
Figure 20: Alternative Future Indo-Pacific 2030 - OPM (Sustainability)	64

Figure 21: Alternative Future Indo-Pacific 2030 - OPM (Economy).....	65
Figure 22: Alternative Future Indo-Pacific 2035 - OPM (Main Criteria)	66
Figure 23: Alternative Future Indo-Pacific 2035 - OPM (Survivability)	67
Figure 24: Alternative Future Indo-Pacific 2035 - OPM (Flexibility)	68
Figure 25: Alternative Future Indo-Pacific 2035 - OPM (Responsiveness).....	69
Figure 26: Alternative Future Indo-Pacific 2035 - OPM (Attainability).....	70
Figure 27: Alternative Future Indo-Pacific 2035 - OPM (Sustainability)	71
Figure 28: Alternative Future Indo-Pacific 2035 - OPM (Economy).....	72
Figure 29: Alternative Future Indo-Pacific 2035 - OPM (Simplicity)	73
Figure 30: Alternative Future Indo-Pacific 2040 - OPM (Main Criteria)	74
Figure 31: Alternative Future Indo-Pacific 2040 - OPM (Attainability).....	75
Figure 32: Alternative Future Indo-Pacific 2040 - OPM (Sustainability)	76
Figure 33: Alternative Future Indo-Pacific 2040 - OPM (Economy).....	77
Figure 34: Alternative Future Indo-Pacific 2040 - OPM (Simplicity)	78
Figure 35: Alternative Future Indo-Pacific 2040 - OPM (Responsiveness).....	79
Figure 36: Alternative Future Indo-Pacific 2040 - OPM (Flexibility)	80
Figure 37: Alternative Future Indo-Pacific 2040 - OPM (Survivability)	81
Figure 38: Alternative Future Europe 2030 - OPM (Main Criteria).....	82
Figure 39: Alternative Future Europe 2030 - OPM (Responsiveness)	83
Figure 40: Alternative Future Europe 2030 - OPM (Attainability)	84
Figure 41: Alternative Future Europe 2030 - OPM (Sustainability)	85
Figure 42: Alternative Future Europe 2030 - OPM (Flexibility).....	86
Figure 43: Alternative Future Europe 2030 - OPM (Survivability)	87

Figure 44: Alternative Future Europe 2030 - OPM (Simplicity).....	88
Figure 45: Alternative Future Europe 2030 - OPM (Economy)	89
Figure 46: Alternative Future Europe 2035 - OPM (Main Criteria).....	90
Figure 47: Alternative Future Europe 2035 - OPM (Simplicity).....	91
Figure 48: Alternative Future Europe 2035 - OPM (Responsiveness)	92
Figure 49: Alternative Future Europe 2035 - OPM (Attainability)	93
Figure 50: Alternative Future Europe 2035 - OPM (Sustainability)	94
Figure 51: Alternative Future Europe 2035 - OPM (Survivability)	95
Figure 52: Alternative Future Europe 2035 - OPM (Economy)	96
Figure 53: Alternative Future Europe 2035 - OPM (Flexibility).....	97
Figure 54: Alternative Future Europe 2040 - OPM (Main Criteria).....	98
Figure 55: Alternative Future Europe 2040 - OPM (Survivability)	99
Figure 56: Alternative Future Europe 2040 - OPM (Responsiveness)	100
Figure 57: Alternative Future Europe 2040 - OPM (Simplicity).....	101
Figure 58: Alternative Future Europe 2040 - OPM (Flexibility).....	102
Figure 59: Alternative Future Europe 2040 - OPM (Attainability)	103
Figure 60: Alternative Future Europe 2040 - OPM (Sustainability)	104
Figure 61: Alternative Future Europe 2040 - OPM (Economy)	105
Figure 62: Model of Space Mobility Utility	108
Figure 63: Alternative Futures on Model of Space Mobility Utility	111
Figure 64: Alternative Future Indo-Pacific 2030 - Option Performance Matrix	112
Figure 65: Alternative Future Indo-Pacific 2035 - Option Performance Matrix	113
Figure 66: Alternative Future Indo-Pacific 2040 - Option Performance Matrix	114

Figure 67: Alternative Future Europe 2030 - Option Performance Matrix	115
Figure 68: Alternative Future Europe 2035 - Option Performance Matrix	116
Figure 69: Alternative Future Europe 2040 - Option Performance Matrix	117

List of Tables

	Page
Table 1: Starship and New Glenn Capabilities	21
Table 2: Fundamental Scale of Absolute Numbers	30
Table 3: Random Index.....	33
Table 4: Cut-Off Consistency Indexes.....	33
Table 5: Top-Level Strategic Guidance Interaction.....	36
Table 6: Approximate Capacity and Velocity Capabilities of C-5M, C-17A, Starship, and New Glenn from Travis AFB, CA (KSUU) to Wake Island (PWAK)	37
Table 7: Specifications of C-5M and C-17A	47

List of Equations

	Page
Equation 1: AHP Principle of Transitivity.....	30
Equation 2: AHP Principle of Reciprocity.....	30
Equation 3: AHP Perfectly Consistent Matrix.....	31
Equation 4: AHP Mean of Normalized Values Method Step 1	31
Equation 5: AHP Mean of Normalized Values Method Step 2	31
Equation 6: AHP Mean of Normalized Values Method Step 3	31
Equation 7: AHP Consistency Ratio.....	32
Equation 8: AHP Consistency Index	32
Equation 9: Algebra of Airlift Productivity	38
Equation 10: Algebra of Airlift Million Ton-Miles Per Day	42
Equation 11: Algebra of Airlift Fleet Capability Short Tons Delivered to the Theater Per Day.....	43
Equation 12: Algebra of Airlift Number of Missions Required	44
Equation 13: Algebra of Airlift Closure	45

List of Acronyms

A2/AD	Anti-Access/Area Denial
ACE	Agile Combat Employment
AFB	Air Force Base
AFDP	Air Force Doctrine Publication
AFPAM	Air Force Pamphlet
AFRL	Air Force Research Laboratory
AHP	Analytic Hierarchy Process
AMC	Air Mobility Command
AMP	Avionics Modernization Program
ANP	Analytic Network Process
ASFB	Air and Space Force Base
ATTLA	Air Transportability Test Loading Activity
CBA	Capabilities-Based Assessment
CI	Consistency Index
CJCS	Chairman of the Joint Chiefs of Staff
CR	Consistency Ratio
CRADA	Cooperative Research and Development Agreement
CRAF	Civil Reserve Air Fleet
CRSF	Civil Reserve Space Fleet
CSAF	Chief of Staff of the Air Force
DABS	Deployable Air Base System
DM	Decision-Maker
DoD	Department of Defense
DTS	Defense Transportation System
FAA	Federal Aviation Administration
FONOPS	Freedom of Navigation Operations
GAMSS	Global Air Mobility Support System
GAO	U.S. Government Accountability Office
GME	Global Mobility Enterprise
HA/DR	Humanitarian Assistance/Disaster Relief
JCIDS	Joint Capabilities Integration and Development System
JCL	Joint Concept for Logistics
JDDE	Joint Deployment and Distribution Enterprise
JI	Joint Inspection
JP	Joint Publication
JWC	Joint Warfighting Concept
MCDA	Multiple-Criteria Decision Analysis
MICAP	Mission Impaired Capability Awaiting Parts
MOG	Maximum Aircraft on Ground
OPM	Overall or Option Performance Matrix
OSD	Office of the Secretary of Defense
OUUSD/A&S	Office of the Under Secretary of Defense for Acquisition and Sustainment

OUUSD/R&E	Office of the Under Secretary of Defense for Research and Engineering
PTP	Point-To-Point
QRF	Quick Reaction Force
RDT&E	Research, Development, Test, and Engineering
RERP	Reliability Enhancement and Re-engineering Program
RVV	Relative Value Vector
SAAM	Special Assignment Airlift Mission
SAF/PA	Secretary of the Air Force Public Affairs
SCM	Space Container Modified
SRV	Suborbital Reusable Vehicle
TPFDD	Time Phased Force Deployment Data
TWCF	Transportation Working Capital Fund
USAF	U.S. Air Force
USINDOPACOM	U.S. Indo-Pacific Command
USTRANSCOM	U.S. Transportation Command
VFT	Value-Focused Thinking
VISA	Voluntary Intermodal Sealift Agreement
VMV	Value for Money Vector

DECISION ANALYSIS WITH THE ANALYTIC HIERARCHY PROCESS AS A METHODOLOGY TO DEVELOP A MODEL OF SPACE MOBILITY UTILITY

I. Background and Research Problem

1.1 Background

The *2018 National Defense Strategy* marked a paradigm shift in the Department of Defense's (DoD) warfighting focus. Decades of countering violent extremist organizations led to strategic atrophy and has yielded near-peer competitors who seek to challenge the rules-based international order (OSD, 2018:1). Great power competition and rapid technological change defines the increasingly complex global landscape, particularly challenging the Joint Force in sustaining its competitive military advantage. To deter the two primary pacing threats of China and Russia from future aggression towards the United States, the Chairman of the Joint Chiefs of Staff (CJCS) has developed the *Joint Warfighting Concept* (JWC). Expanded maneuver is a key element of the JWC and encompasses four functional battle areas (Vergun, 2021). The first battle area involves contested logistics or logistics under attack, particularly in the non-permissive U.S. Indo-Pacific Command (USINDOPACOM) area of responsibility, where great power competition and the tyranny of distance will challenge the United States' ability to sustain its military supply chain.

A Defense Science Board Task Force recognized that resilient and unconstrained logistics is critical for U.S. power projection against near-peer adversaries (OUSD/R&E, 2018:1). U.S. Air Force (USAF, 2021b:2) doctrine acknowledges that an adversary's capacity to deny area access reduces its capability to project airpower with airlift, thereby complicating the Joint Force's maneuver across the competition continuum. Airlift is

currently the most expeditious method of cargo delivery in the Strategic Mobility Triad (CJCS, 2017:I-5). The Joint Force, particularly the Immediate Response Force, is heavily reliant on strategic airlift to deploy worldwide within 18 hours of notification. In some scenarios, 18 hours may not be expeditious enough. Further complicating matters is the potential infrastructure degradation of forward operating locations which may limit the ability for airlift to sustain warfighters at the battle's edge. In a high-end fight, Joint Force commanders will rely on sustainment, one of the seven Joint functions, to maintain operations until mission accomplishment and re-deployment of forces (CJCS, 2019b:I-1). Today's airlift capacity overwhelmingly operates in permissive operational conditions and are extremely vulnerable to interdiction by adversaries. Future competition with near-peer adversaries highlights a requirement for a strategic lift capability with increased speed and range over current capabilities while maintaining existing ton-mile capacity.

Recognizing that the United States lives in a world with aggressive and capable global competitors, the Chief of Staff of the Air Force (CSAF) posits that the USAF must understand how our adversaries plan to conduct future warfare and that it must prioritize capabilities that will make it competitive in the high-end fight (Brown, 2020:11). The *CSAF Action Orders* specifically calls for industry collaboration to mitigate supply chain vulnerability and execute combat replenishment in potentially protracted conflicts (Brown, 2020:10). Under this vision, the Air Force has developed the Vanguard program whose vision is to “dominate time, space, and complexity across all operating domains to project power and defend the homeland” with the main objective to “develop and deliver transformational strategic capabilities” (USAF, 2020:7). One of four Vanguards for fiscal year 2022 is Rocket Cargo which has the potential to provide the warfighter with a leap-

ahead spacelift capability for point-to-point (PTP) logistics deployment and sustainment. A distinguishing characteristic of a Vanguard is the commitment from the USAF to fully onboard and transition the technology once matured. Rapid advances in commercial rocket technology increasingly make space transportation a potential fourth mode of transportation, making it the fastest PTP capability to deliver cargo to the warfighter with flight times under an hour as shown in Figure 1. The commercial space launch industry is developing the largest rockets ever designed offering both higher payload capacity and significantly lower cost per pound of cargo and with built-in reusability utilizing refurbished first-stage boosters. The DoD finds Rocket Cargo to be a compelling space capability to project rapid global mobility in a world of great power competition because of its ability to serve as an offset, or an asymmetric advantage, against an adversary.



Figure 1: Point-to-Point Space Transportation Concept of Operations (AFRL, 2021)

1.2 Research Problem

Utilizing rockets to transport point-to-point cargo is more expensive than using traditional methods of airlift by five to 20 orders of magnitude depending on full rocket reusability capabilities and frequency of launches (Koether, 2018:14, 17-18; Kwast, 2016:22). Similarly, airlift is more expensive than sea and land-based methods by comparable orders of magnitude (Prevett, 2007:5; CJCS, 2017:I-5). Regardless of cost, a Combatant Commander selects airlift in certain scenarios based on military necessity as the most preferred choice given other criteria. Therefore, cost is not always the only or most important driving factor when selecting a power projection platform from the Strategic Mobility Triad. Criteria such as responsiveness, simplicity, flexibility, economy, attainability, sustainability, and survivability factor in with varying degrees of applicability. Given these criteria, there are potential scenarios when PTP spacelift may be the preferred option to sustain the Joint Force.

1.3 Research Objectives

This research project has three primary objectives:

Objective 1: Utilize multiple-criteria decision analysis (MCDA) to build a capabilities-based assessment to determine the preferred strategic mobility platform to sustain the Joint Force under a variety of alternative futures. Consider criteria from the following top-level strategic and planning guidance:

- Joint Publication (JP) 4-0, *Joint Logistics* (CJCS, 2019b)
- JP 3-17, *Air Mobility Operations* (CJCS, 2019a)

- Air Force Doctrine Publication (AFDP) 3-36, *Air Mobility Operations* (USAF, 2019)
- Model of Air Mobility Utility (Salmi, 2020)
- Table of Modality Decision Criteria (Prevett and Anderson, 2017)
- *Algebra of Airlift* (Brigantic and Merrill, 2004) and Air Force Pamphlet (AFPAM) 10-1403, *Air Mobility Planning Factors* (USAF, 2018)

Objective 2: Using methods of assessment from Objective 1, determine mission sets and scenarios where Rocket Cargo is the preferred option. Discuss the various strengths and weaknesses of each platform in the context of criteria derived from Objective 1.

Objective 3: Develop a Model of Space Mobility Utility to provide future strategists a foundational resource of fundamental Space Mobility Factors to consider when framing the utility of spacelift as a strategic mobility option.

1.4 Research Focus

Research focused on four strategic lift alternatives, including two USAF strategic airlift aircraft and two commercial spacecraft: Lockheed Martin C-5M Super Galaxy, Boeing C-17A Globemaster III, SpaceX Starship, and Blue Origin New Glenn. The C-5M and C-17A are the primary strategic airlift alternatives selected since their cargo payload capacities meet or exceed the payload capacities of both Starship and New Glenn. The two spacecraft variants are the primary spacelift alternatives since they are current front runners to demonstrate United States Transportation Command (USTRANSCOM) PTP cargo capability in the next three to five years. Future research

and analysis can compare other emerging space vehicles using techniques demonstrated here with an expanded set of airlift platforms using Defense Planning Scenarios.

1.5 Investigative Questions

To support the Joint Force's ability to move and maneuver, what air mobility criteria can a decision-maker (DM) apply to space mobility for PTP logistics?

What is the relative importance of such criteria (i.e., what is the value to the DM) under a given scenario?

What is the relative importance of each alternative with respect to each criterion under a given scenario?

Which alternative is preferred given criteria and alternative preferences?

What DoD mobility missions are uniquely enabled by spacelift? What are some drawbacks to utilizing spacelift for the mobility mission?

1.6 Methodology

MCDA empowers DMs to systematically select the best alternative under a specific scenario given set criteria. The MCDA tool used in this research is the Analytic Hierarchy Process (AHP) which provides the ability to consider qualitative data in a systematic way. It is based on three basic principles of decomposition, comparative judgments, and a synthesis of priorities (Saaty, 1986). Four strategic mobility platforms will compete under specific alternative futures utilizing criteria from military doctrine and previous research on mobility and modal choice decisions. This methodology will allow DMs to set a goal, evaluate alternatives given a complex set of criteria, extract quantifiable measures from their evaluations, create a common decision-making platform

to effectively communicate with cross-functional teams, and execute their decision process systematically.

1.7 Assumptions and Limitations

A significant assumption for this research is that SpaceX and Blue Origin will successfully develop the Starship and New Glenn to reliably support PTP space mobility capability in the 2024-2025 timeframe as stated in the Cooperative Research and Development Agreements (CRADAs) set forth by USTRANSCOM (2020:1; 2021:15). The USAF is unambiguous in not bearing the burden of developing its own rocket technology to support PTP cargo delivery but will instead leverage commercially led launch vehicle research, development, test, and engineering (RDT&E). USTRANSCOM desires to quickly implement the commercial technology for mobility purposes to position the DoD to be an early adopter (AFRL, 2021:3).

Currently, the Starship and New Glenn are *conceptually* feasible to support DoD global logistics transportation requirements (AFRL, 2021:4). This includes:

- Commercial capability for a one-way transport from a prepared launch facility to an austere site with a somewhat prepared landing site, utilizing multi-modal transportation options to return the rocket to an established spaceport.
- Commercial capability for a round trip routine delivery between two spaceports with existing logistics infrastructure.
- Commercial capability for an airdrop of equipment from a prepared launch facility to a designated location.

There is no current capability to rapidly onload/offload cargo from a rocket with comparable sequence of events, typically 2-4 hours, as traditional airlift platforms. However, SpaceX is developing a system called the Starship Launch and Catch Tower which is conceptually able to catch and rapidly reconstitute first-stage boosters and may have the capacity to rapidly onload/offload cargo (Williams, 2021:1). Onboarding this type of capability is a part of the USTRANSCOM CRADA with SpaceX to ensure compatibility with existing DoD infrastructure and processes.

The Air Force Research Laboratory (AFRL, 2021:1-32), as the Secretary of the Air Force designated lead for the Rocket Cargo Vanguard program, has delegated various lines of effort across the DoD that serve as further assumptions for this research focus:

- Technical and engineering feasibility to include rocket reusability
- Mitigating policy and law issues to include international and diplomatic concerns
- Business case analysis and funding sources (Civil Reserve Air Fleet-CRAF or Voluntary Intermodal Sealift Agreement-VISA equivalents)
- Landing zone requirements and environmental suitability (spaceports)
- Materiel handling equipment requirements to include hazardous cargo
- Joint inspection requirements for orbital/sub-orbital operations
- Cargo onload/offload capabilities to include a standardized pallet system and digital twin to accelerate loadmaster cargo planning
- Command and control and cybersecurity
- In-transit asset visibility and chain of custody
- Rocket recovery, integrating with multimodal if necessary

- End-to-end time considerations, including delivery to and from the launch pad
- Projected training and manning requirements for Space Port Expeditors

Excessive materiel pre-positioning, logistics delivery to launch pad, and last-mile onload/offload timelines must not negate the inherent velocity enabled by Rocket Cargo. The frequency of launches by commercial partners must make PTP spacelift not absolutely cost prohibitive for the DoD. Figure 2 highlights how cost per kilogram of payload rapidly decreases as flight rates increase with a 3x reduction in launch costs at approximately 80 launches per year and a 10x reduction in launch costs at approximately 550 launches per year (Kwast, 2016:3). Further cost assumptions include launch facility safety maintenance and lease, transportation of cargo to and from the launch site, fuel depot costs, personnel, training, and rocket refurbishment cost. The scope of this research project will not specifically address each of the Vanguard lines of effort and will remain limited to determining the scenarios and mission sets when Rocket Cargo may be the preferred strategic mobility option.

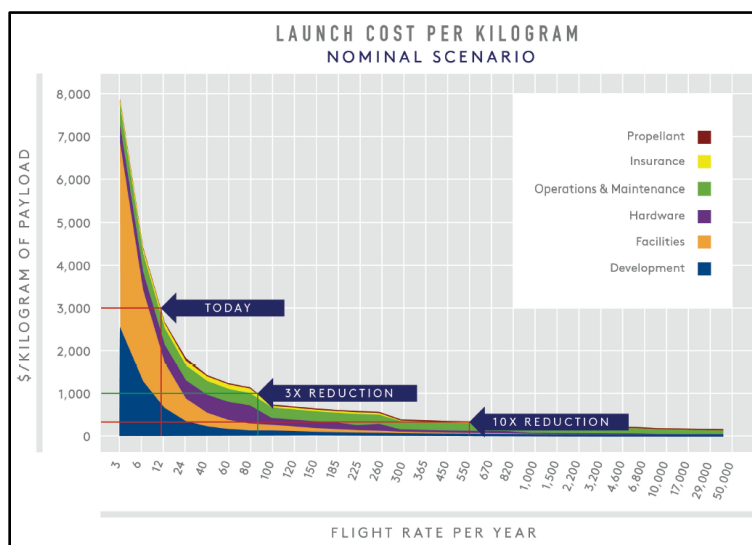


Figure 2: Cost Per Kilogram Rapidly Decreases as Flight Rate Increases (Kwast, 2016:3)

1.8 Summary of Findings

This research identifies air mobility-focused logistics criteria that can be applied to space mobility in the context of terrestrial point-to-point cargo delivery. Using decision analysis as a methodology to decompose, comparatively judge, and synthesize priorities under a specific alternative future provides clarity to mission sets that may favor unique spacelift capability versus air mobility. The methodology is applied to develop a Model of Space Mobility Utility (Figure 3) which provides future strategists a foundational resource of fundamental Space Mobility Factors to consider when framing the utility of spacelift as a strategic mobility option for the Combatant Commander.

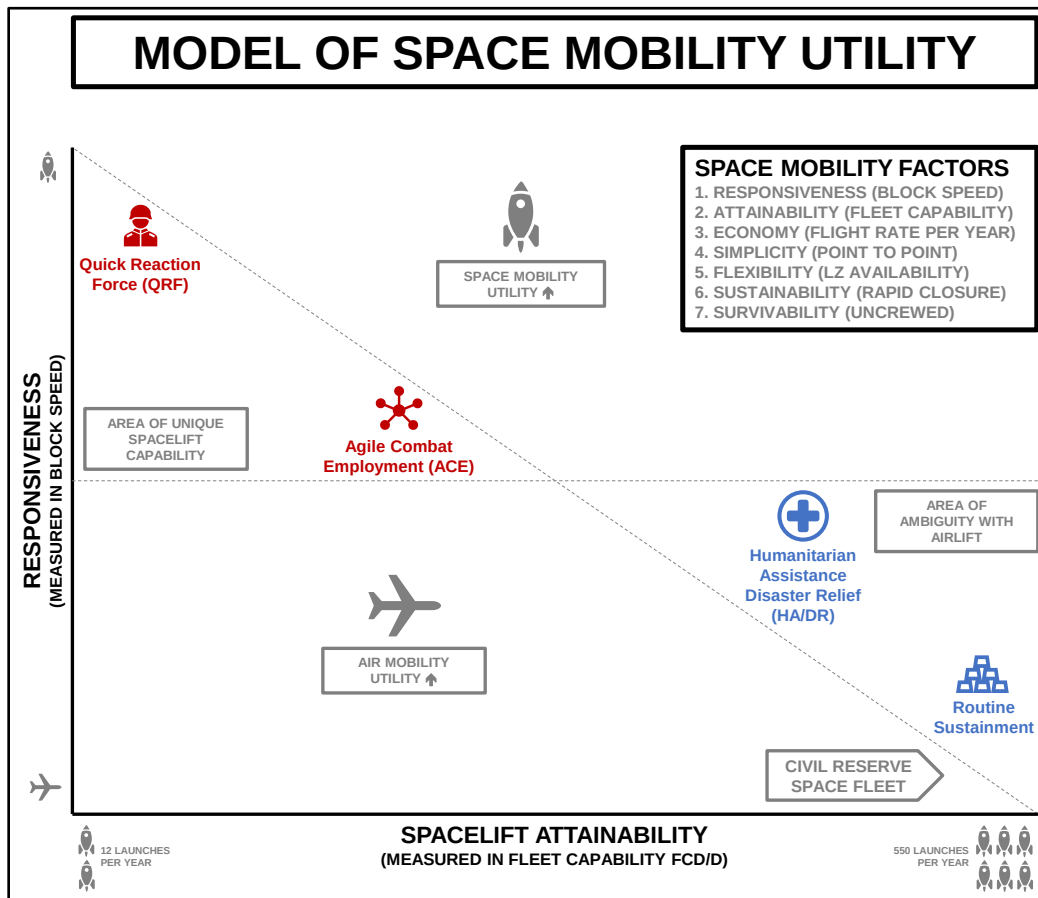


Figure 3: Model of Space Mobility Utility

1.9 Implications

Today's airlift platforms have great difficulty operating in non-permissive, anti-access, and area denial environments. The tyranny of distance in the Indo-Pacific further amplifies this difficulty. It is probable that near-peer adversaries will compromise forward operating locations. Rocket Cargo could provide the Combatant Commander a solution to rapidly restore mission capability at a dispersed forward operating location in a contested environment where no other feasible solutions exist, deliver humanitarian relief in the fraction of the time it would take airlift, or serve a Quick Reaction Force's logistics requirement. This offset capability also serves as a powerful deterrent to any adversaries. The speed at which commercial industry is delivering real capabilities presents an emerging opportunity for the DoD logistics enterprise to rapidly build the connections between PTP spacelift and existing defense and civil infrastructure to include the Global Air Mobility Support System (GAMSS). Building early interoperability with the commercial spacelift industry will help to ensure lower long-term RDT&E costs to the DoD and ensure that the Joint Force's interests are built-in to the capability.

II. Literature Review

2.1 Global Mobility Enterprise

As the air component to USTRANSCOM, Air Mobility Command (AMC) has the core mission of ensuring Rapid Global Mobility for the Joint Force and thus plays a critical role in the JWC's battle area of contested logistics. AMC maneuvers the Joint Force's personnel and materiel with traditional air mobility platforms that range from tactical to strategic airlift utilizing the Global Mobility Enterprise (GME) as its backbone (CJCS, 2019a:I-8). The GME supports the Combatant Commanders by optimizing the velocity and capacity of the air mobility system (USAF, 2019:3). There are concerns by both academics and lawmakers that the GME will be unable to support global efforts in the event of a conflict in a non-permissive, high-intensity conflict (GAO, 2021:1; Owen, 2017:1). Air Force leadership recognizes the importance that Rapid Global Mobility brings to the fight in its Fiscal Year 2022 Posture Statement to Congress:

The Air Force capability that most directly, and physically, supports both the Air Force and our joint teammates is rapid global mobility. Airmen conduct Rapid Global Mobility operations to project and sustain combat power by moving personnel, [materiel], fuel, and supplies across the globe, in and through permissive and contested threat environments on short timelines. The combination of speed, range, flexibility, and responsiveness is what differentiates air mobility operations from other forms of transport and is critical to multi-modal operations contributing to a higher pace for Joint All-Domain Operations. As threats evolve and the United States can no longer operate from well-established fixed bases, rapid global mobility is the lynchpin to persistent logistics, and we are examining unique ways to utilize mobility aircraft. (USAF, 2021d:9)

A Defense Science Board Task Force recognizes that the DoD has enjoyed a logistics overmatch in that its ability to transport, supply, and resupply the Joint warfighter anywhere in the world has been largely unchallenged for decades (OUSD/R&E, 2018:1). AMC's airlift platforms have enjoyed relative permissiveness in

their operations and a concept called Agile Combat Employment (ACE) will be increasingly necessary under great power competition (Van Ovost, 2021:1). ACE is the solution to many of the exploratory challenges posed in the Joint Concept for Logistics (JCL) such as the ability to “rapidly aggregate, disaggregate, and re-aggregate Joint Forces anywhere in the world, including in a contested environment” (CJCS, 2015:16). Key tasks under ACE include resilient and distributed logistics, operating in contested environments, rapid response, dispersed and agile operations, execution across the full spectrum of operating locations, Joint and coalition integration, and transportation and movement (Mills and others, 2017:32). Dynamic force employment of the Joint Force will be dependent upon the GME to execute these key ACE operations in an environment with logistics under attack. The United States’ primary pacing threat, China, has been critical of ACE, specifically raising three weaknesses: 1) countries within its nine-dash line may not permit the U.S. to operate out of their sovereign air bases, 2) the U.S. will still be heavily reliant on its permanent bases in the region, and 3) the People’s Liberation Army can counteract ACE by interrupting the U.S. kill chain (Solen, 2020:14). Furthermore, the People’s Liberation Army has prioritized their “ability to impose unacceptable costs on the access of, or freedom of maneuver within, China’s first and second island chains” (Peltier, 2020:4). The Office of the Secretary of Defense estimates that China will have a fully modernized military by 2035, able to potentially exploit the weaknesses in the U.S. ACE concept (OSD, 2020:4). Rocket Cargo can provide the foundation for an adaptive logistics system that can meet operational ACE requirements as operations grow in scale due to the increase in operating locations (USAF, 2021a:9).

- Resilient and Distributed Logistics – A potentially degraded hub and spoke enroute system and limited aerial refueling assets limits the maneuverability of traditional airlift platforms in a contested environment. Figure 4 highlights the vulnerability of the hub and spoke enroute system where an adversary could render an intermediate stop inoperable. Like air bridge operations in Figure 5, Rocket Cargo, without the need for an intermediate stop or air refueling, can directly deliver a capability like the Deployable Air Base System in under an hour to restore a forward operating location's ability to meet sustainment requirements.

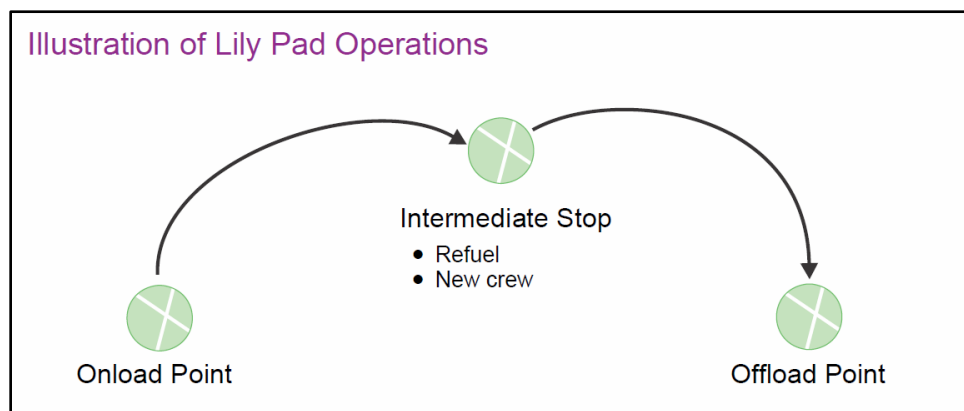


Figure 4: Illustration of Lily Pad Operations (CJCS, 2019a:V-15)

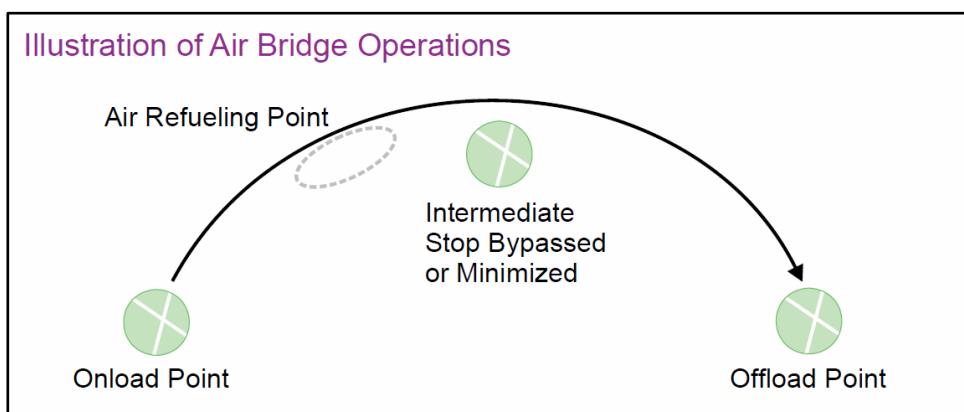


Figure 5: Illustration of Air Bridge Operations (CJCS, 2019a:V-15)

- Operating in Contested Environments – PTP spacelift can provide rapid resupply to a degraded or damaged airfield at an austere location with constant custody, in-transit visibility, and command and control of materiel. Theater-specific threats will cause airlift platforms to disperse and maneuver, potentially leaving certain locations unsupported.
- Rapid Response – Rocket Cargo enables the Combatant Commander to quickly respond to a threat anywhere in the world when faced with truncated warning time. Pre-positioning critical war reserve materiel in a fractional orbit or on ground alert status can provide even greater responsiveness.
- Dispersed and Agile Operations – With force disaggregation a priority in ACE, Combatant Commanders can use Rocket Cargo to support dispersed operations and introduce unpredictability in an adversary’s strategic calculus. It can also deliver the speed and agility to meet Joint Force requirements across the continuum of force projection capability and base-level resiliency (Figure 6).

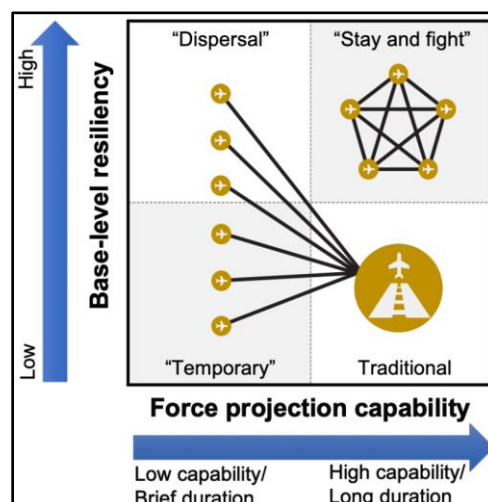


Figure 6: Integrated Basing in the Context of Base Archetypes (Mills and others, 2017:37)

- Execution Across the Full Spectrum of Operating Locations – PTP spacelift enables warfighter dispersal to smaller, more austere locations by sustaining the force after an attack. In an Indo-Pacific scenario, this could enable continued operations within the first and second island chains.
- Joint and Coalition Integration – There should be seamless interoperability with Joint warfighters as there is with airlift using the existing joint inspection (JI) system.
- Transportation and Movement – ACE operations will require Joint Forces to have significant transportation support. Pre-positioned materiel may be inaccessible in a high-end fight, therefore sustaining and resupplying critical materiel at alternative operating locations can be enabled by Rocket Cargo.

As primary executor of the Joint Deployment and Distribution Enterprise (JDDE), the National Command Authority tasks USTRANSCOM to project and sustain the Joint Force anywhere in the world at a time and place of the Nation's choosing (OUSD/A&S, 2020:7). Complicating the JDDE's decision calculus is the rapid pace of warfare combined with the tyranny of distance in the Indo-Pacific region. The Pentagon intends to meet the challenge of contested logistics with a concept called persistent logistics, responding to "warfighter needs at the speed of relevance in an unpredictable environment" (Berry, 2020:6). Underpinned by posturing for strategic inter-state competition, the concept of persistent logistics responds to warfighter needs at the speed of relevance and senses to create shared understanding in real time. The ACE concept is critical to the theory of persistent logistics with logistics under attack.

To execute the ACE concept, the GME relies on the strategic airlift capability of AMC. Utilizing the two main strategic airlift platforms in the C-5M and C-17A, AMC supports the Joint warfighter with movement, maneuver, and sustainment. In addition, the C-5C is an available Space Cargo Modified airlift platform utilized by the National Aeronautics and Space Administration to move outsized space cargo; Rocket Cargo could be pre-positioned by the C-5C, or Space Container Modified (SCM) platform (USTRANSCOM, 2019:123). The Joint Staff defines air mobility as “the rapid movement of personnel, materiel, and forces to and from, or within, a theater by air” (CJCS, 2019a:I-1). Strategic airlift is a capability that provides the Combatant Commander with an expeditious method to project and sustain the Joint Force across the world. The primary challenge for the GME going forward is to support the steadily increasing logistics requirements of the Joint Force, the growing complexity of logistics operations, and the advancement of adversary anti-access and area-denial (A2/AD) capabilities. The emergent competencies of near-peer adversaries challenges air mobility’s key performance indicators of velocity, capacity, sustainability, and attainability. To continue supporting the warfighter at the speed of relevance, USTRANSCOM has identified commercial PTP space transportation as an option to provide the JDDE with a unique capability that positively disrupts the traditional theories of rapid global mobility.

2.2 Commercial Spacelift Industry

The Department of the Air Force announced Rocket Cargo as one of four Vanguard programs in its Science and Technology strategy for 2030 and beyond (SAF/PA, 2021). AFRL is leading the effort to synchronize commercial spacelift partners and Defense Transportation System (DTS) stakeholders to explore the idea of enabling truly rapid payload delivery unbounded by the traditional constraints of distance and time. AFRL (2021:1) envisions the technology to support missions including emergency resupply to restore loss of mission capability, humanitarian assistance and disaster relief, and ultimately routine delivery of cargo worldwide (Figure 7 is an artist's rendering of the transformational capability). The Joint logistics over-the-shore capabilities of Rocket Cargo provide the Combatant Commander with the operational flexibility to choose from a wider variety of off-load locations. In the USAF's Fiscal Year 2022 RDT&E budget, it describes Rocket Cargo as follows:

The Department of the Air Force seeks to leverage the current multi-billion dollar commercial investment to develop the largest rockets ever, and with full reusability to develop and test the capability to leverage a commercial rocket to deliver AF cargo anywhere on the Earth in less than one hour, with a 100-ton capacity. Provides a new, faster and cheaper solution to the existing TRANSCOM Strategic Airlift mission. (USAF, 2021c:289-290)



Figure 7: Artist's Rendering of Rocket Cargo for Agile Global Logistics (SAF/PA, 2021)

Delivering PTP cargo via suborbital reusable vehicles (SRV) is not a new concept. A CRADA between the U.S. Marine Corps and the University of North Dakota investigated a concept called Small Unit Space Transport and Insertion that would transport a Marine squad of 13 infantrymen to any potentially hostile area in the world in under two hours (Jurist and others, 2009). SRVs, a commercially developed reusable space platform that travel just beyond the threshold of space, are part of an emerging industry interested in serving new markets. The following are companies with published reusable first stage rockets (FAA, 2018:19):

- PLD Space, Spain (Arion 2)
- SpaceX, USA (Falcon Heavy) (Figure 8)

- Blue Origin, USA (New Glenn) (Figure 9)
- LinkSpace, China (New Line 1)
- OneSpace, China (OS-M1)



Figure 8: Two SpaceX Falcon Heavy Boosters Landing (“Side Boosters Have Landed,” 2019)

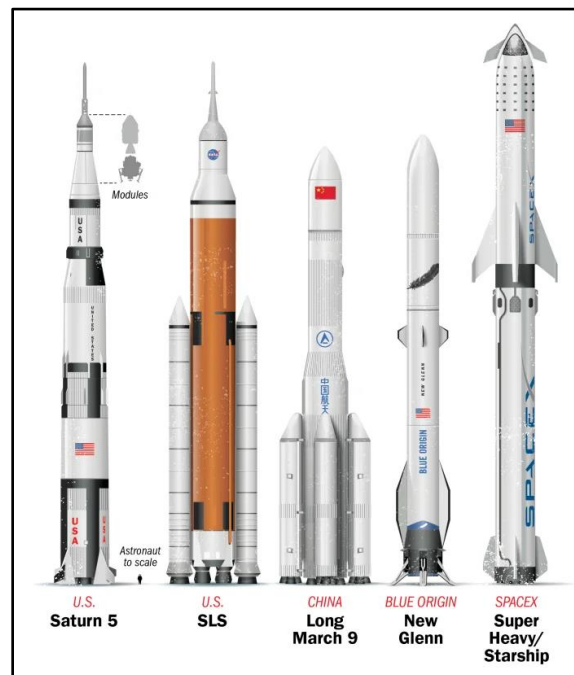


Figure 9: Starship and New Glenn Size Comparison (“Dueling Superpowers, Rival Billionaires. Inside the New Race to the Moon,” 2022)

SpaceX is developing Starship, a rocket primarily designed to support humans as a multi-planetary species (“Starship Users Guide Revision 1.0,” 2020:1). As far as launch costs are concerned, the Starship’s predecessor, Falcon Heavy, conceptually has the performance to launch 140,000 pounds to low-earth orbit and costs \$640 per pound of cargo as compared to a C-5M which ranges anywhere from \$3-5 per pound of cargo (Koether, 2018:29). Kwast (2016:3) predicts that cost per kilogram of payload rapidly decreases as launches increase with a 3x reduction at approximately 80 launches per year and a 10x reduction with approximately 550 launches per year (Figure 2). Furthermore, Koether (2018) calculated that a fleet of 50 Falcon Heavy’s could boost the cargo capacity of USTRANSCOM by almost 37 million-ton-miles per day which would double the overall organic airlift capacity (excluding CRAF) during a time of great conflict. This assumes built-out spaceport infrastructure or a multi-modal rocket recovery system which would be able to reconstitute the first-stage booster. In 2021, Blue Origin signed a CRADA with USTRANSCOM to utilize the New Glenn for PTP cargo delivery with smaller, more tactical payloads than offered by the Starship (USTRANSCOM, 2021:15). Table 1 is an approximate breakdown of Starship and New Glenn capabilities.

Table 1: Starship and New Glenn Capabilities (“New Glenn Payload User’s Guide Revision C,” 2018:57; “Starship Update,” 2022; “Starship Users Guide Revision 1.0,” 2020:2)

Characteristic	Starship	New Glenn
Payload Fairing Diameter (m)	9	7
Payload Fairing Height (m)	50	21.9
Payload Volume (m ³)	1,100	450
Useful Mass to Low Earth Orbit (metric tons/lbs)	150 / 330,693	45 / 99,208

The U.S. space commercial sector is the first in the world to demonstrate commercial orbital cargo delivery and commercial first-stage reusability but the Chinese are not far behind having conducted test flights of reusable suborbital vehicles (Olson and others, 2021:8, 23; Jones, 2021). It is part of the China's long-term plan after 2030 to possess a "space multi-dimensional projection system to meet the rapid reaction requirements of transportation projection capabilities, in the event of war anywhere around the globe" (Peltier, 2020:23). Reusable PTP rockets is a technology that will upend traditional warfighting concepts. With the commercial sector driving the RDT&E of reusable rockets, state and non-state actors may have access to the technology, risking the conventional overmatch to which the U.S. has grown accustomed (Kwast, 2016:5).

USTRANSCOM, in CRADAs with Exploration Architecture Corporation (xArc), SpaceX, and Blue Origin, is working with the space launch industry and within the DoD to research the normalization of cargo delivery via spacelift. SpaceX is exploring three primary types of missions outlined in Figure 10. The one-way mission, like a USTRANSCOM Special Assignment Airlift Mission (SAAM), would support a Quick Reaction Force or urgent resupply to austere locations; it assumes either that the rocket will never be reused or will be recovered using a multi-modal option. The two-way mission, like a typical AMC airlift or CRAF mission set, would support routine resupply missions between established spaceports. This two-way mission assumes an existing commercial spaceport infrastructure reinforced by enroute Space Force spaceports which may be located throughout the GAMSS (FAA, 2018:22). The airdrop option, like a Special Operations Low Level mission, would support the Joint Special Operations Command or a humanitarian assistance and disaster response situation (HA/DR). AFRL

has previously explored delivering humanitarian supplies using reusable launch vehicles but the major constraint was not technical but rather the “justification of the non-recurring cost that goes into developing and fielding a reusable launch vehicle” (Hellman and others, 2015:2). Utilizing the smaller payload New Glenn, another use case would be the rapid delivery of mission impaired capability awaiting parts, or MICAP, especially in an ACE scenario.

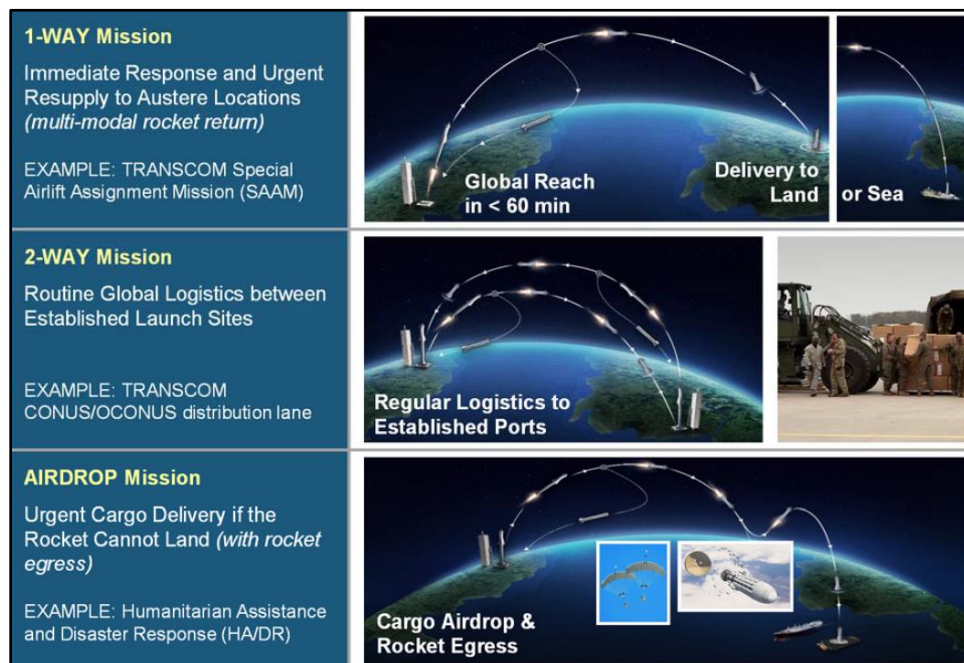


Figure 10: Point-to-Point Space Transportation Capabilities Explored Under the AFRL Rocket Cargo Vanguard Program (AFRL, 2021)

Army General Stephen Lyons, former commander of USTRANSCOM, is an ardent supporter of the Air Force Vanguard project and believes that being able to move C-17A sized payloads across the globe in under an hour is the logistics of the future (“Rocket cargo delivery gets big boost,” 2021). The current commander of USTRANSCOM, Air Force General Jacqueline Van Ovost likewise views Rocket Cargo as a potentially disruptive PTP transportation capability (NDTA, 2021). As far as

timelines are concerned, SpaceX is projecting launches for its Starship platform for PTP space transportation capability in the 2024-2025 timeframe (Harper, 2021). AFRL has signed a \$102 million contract with SpaceX to gain access to commercial orbital launches and booster landings to collect critical data on performance and environmental impact and to further investigate cargo bay designs that support rapid onload and offload that is compatible with USTRANSCOM's current intermodal containers (Erwin, 2022). Elon Musk claims that SpaceX's latest plan is to engineer one-hour turnaround times for the first-stage booster by catching it with the Launch and Catch Tower arm ("Starship Update," 2022; Williams, 2021). SpaceX is also investigating the feasibility of applying the current CRAF construct to a potential Civil Reserve Space Fleet (CRSF) whereby the U.S. government would simply contract its spacelift requirements to industry. The commercial development of PTP space transportation is aggressively driving down launch costs and timelines which provides the DTS with a capability free of any RDT&E costs besides use-case investigations.

Retired Lieutenant General Steven Kwast, in *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges*, summarized the choice the USAF must make in the coming years:

Growing threats to forward bases, today's space architecture, and our capabilities to hold targets at risk, present the Air Force with stark choices. We can double down on a forward based model of power projection or develop a different way to project power that offsets these threats and uplifts the capability of today's force. Recent private sector developments in access to space could open the door for a new concept for airpower. If realized these capabilities could fundamentally change the USAF's power projection paradigm, while building new strategic options for the nation. (Kwast, 2016:II)

The selection of Rocket Cargo as one of four Vanguards by the Air Force Scientific Advisory Board for its 2030 Science and Technology Strategy highlights a Department of the Air Force commitment to onboard this transformational future force warfighting capability (USAF, 2020:4).

2.3 Analytic Hierarchy Process

Balancing risk and reward under challenging scenarios are something all senior DMs in the DoD face. It would be ideal to make those tough decisions with their cross-functional teams in a simple and systematic way. MCDA is frequently utilized to aid DMs in selecting the best alternative under a given scenario; the main goals of MCDA are to evaluate a complicated set of criteria, extract quantifiable measures from subjective or qualitative evaluations, create a common decision-making platform to streamline communication, and execute decision processes systematically (Temucin, 2019:157). The MCDA tool utilized in this research is Professor Thomas L. Saaty's Analytic Hierarchy Process (AHP) which provides the ability to consider qualitative data in a systematic way (Saaty, 1987:161). It is based on three basic principles of decomposition, comparative judgments, and a synthesis of priorities (Saaty, 1986:1). The AHP is relatively simple to use, allows for re-evaluating and re-planning, can incorporate subjective factors, and measures the consistency of judgments (Liberatore and Miller, 1995:89). It also fundamentally prevents mere number crunching by the DM and enables a decision theory that is relatively invariant to politics and human behavior (Saaty, 1990:10).

The AHP allows us to choose factors that are important for a DM to select the best alternative under any given situation; these factors form a hierarchic structure

beginning from an overall goal, incorporating criteria, and determining preferred alternatives (Saaty, 1990:9). The hierarchical decomposition of the decision must be a thorough representation of the problem, but not so specific that it loses its sensitivity to changes in criteria; the decomposition must also consider the environment surrounding the problem, identify the issues that contribute to the solution, and provide an overall view of the complex situations inherent in the situation to help the DM assess whether the criteria is of the same magnitude. The decision must use no more than 7 ± 2 criteria to not lead to large pairwise matrices that lead to lower outcome accuracy and reliability (Saaty, 2008:266). Using the principle of comparative judgments, the DM applies pairwise comparisons to all the combinations of criteria with respect to the alternatives. These pairwise comparisons result in a derivation of local priorities. The DM then synthesizes the local priorities of criteria with the global priorities of alternatives, producing a hierarchic composition of priorities (Saaty, 1990:10).

The AHP continues to be the subject of discussion in the decision analysis community. Saaty (2008:315), Coyle (2004:2), and Whitaker (2007:948-961) comprehensively address general criticisms of the AHP and why it is mathematically defensible. A primary point of contention is AHP's use of a ratio scale of measurement that can occasionally lead to rank reversal if the analysis adds new alternatives. For a defined set of alternatives like in this research, rank reversal is not an issue (Liberatore and Miller, 1995). A secondary criticism is AHP's rigid linear scale but Saaty makes the point that the DM must be able to convey their priorities without using rigorous mathematical definitions and that "the AHP is a theory for the human level of coping and not a number-crunching device for measuring a single attribute from zero to infinity"

(Saaty, 1991:911). This research considered but rejected the use of Value-Focused Thinking (VFT) due to requiring an exhaustive list of alternatives (Dillon-Merrill and others, 2008:14; Jurk, 2002:31; Keeney, 2008:14). For future research that may consider an exhaustive list of alternatives such as all airlift and spacelift platforms, VFT may be more appropriate.

A wide-ranging set of researchers, companies, and governments have used AHP to model and make real-world decisions in various industries. The number of AHP applications number in the thousands and there continue to be state-of-the-art integrations and applications of the AHP (Ho and Ma, 2018:399). AHP was used by IBM as part of its quality improvement strategy to design its award-winning AS/400 computer, by Xerox Corporation to allocate close to a billion dollars of research and development funds, and by Ford Motor Company to establish priorities for criteria to improve customer satisfaction (Saaty, 2008:253). Related to the scope of this research, Liberatore and Miller utilized AHP to consider the two transportation modes of sealift and airlift and concluded that it offered a “comprehensive, yet flexible methodology for addressing transport carrier and mode selection problems” (Liberatore and Miller, 1995:112). Prevett and Anderson (2007:1) built upon this work and used a form of AHP, the Analytical Network Process (ANP), to build a decision model for USTRANSCOM to choose between sealift and airlift for global mobility. Prevett and Anderson (2017:7) expanded their research ten years later to use ANP to incorporate qualitative factors into multi-criteria global modal choice decisions.

Decision making is of obvious particular interest in the military and the increasingly complex global landscape requires that DMs use their judgments to consider

multiple perspectives and criteria. The military's decision-making process relies heavily on the judgments of teams and leaders when applying doctrine (Wampler and Salter, 1998:15). A basic principle in the AHP is that a valid outcome depends on establishing priorities (or judgments) for the criteria, establishing priorities for the alternatives with respect to each criterion, and synthesizing the results. The DoD's Capabilities-Based Assessments (CBA), conducted under the Joint Capabilities Integration and Development System (JCIDS), share similar underlying principles with the AHP (CJCS, 2009). The CBA and the AHP both require a well-understood problem, a consideration of functions or criteria, and an analysis of types of solutions.

III. Methodology

3.1 Analytic Hierarchy Process Flow

This research utilizes the AHP to compare the C-5M, C-17A, Starship, and New Glenn under specific scenarios utilizing criteria from CJCS JP 4-0, *Joint Logistics*, CJCS JP 3-17, *Air Mobility Operations*, AFDP 3-36, *Air Mobility Operations*, Salmi's Model of Air Mobility Utility, Prevett and Anderson's Table of Modality Decision Criteria, Brigantic and Merrill's *Algebra of Airlift*, and AFPAM 10-1403, *Air Mobility Planning Factors*. The AHP methodology will allow DMs to set a goal, evaluate alternatives given a complex set of criteria, extract quantifiable measures from their evaluations, create a common decision-making platform to effectively communicate with cross-functional teams, and execute their decision process systematically. In this research, the author (Major Kristofer Fernandez), is the DM executing the AHP methodology toward a theory of Space Mobility Utility.

The steps of the AHP are listed below with a flow chart in Appendix A (Saaty, 2008:254-271; Coyle, 2004:10-11).

1. Define the goal.
2. List the various criteria to assess the alternatives.
3. List the various alternatives to fulfill the goal.
4. Build the hierarchy. Design a hierarchy chart beginning with the goal (a statement of the overall priority), followed by the objectives (the criteria needing consideration), and then the alternatives (which are available to reach the goal).
5. Generate an Overall Performance Matrix (OPM). Pairwise comparison each set of criteria to assign intensities that represent relative importance using the Saaty

Fundamental Scale of Absolute Numbers in Table 2. Develop a pairwise comparison matrix ensuring the principles of transitivity (Equation 1) and reciprocity (Equation 2).

Table 2: Fundamental Scale of Absolute Numbers (Saaty, 2008:257)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
2	Weak or slight	-
3	Somewhat more important	Experience and judgement <i>slightly</i> favor one over the other.
4	Moderate plus	-
5	Much more important	Experience and judgement <i>strongly</i> favor one over the other.
6	Strong plus	-
7	Very strong or demonstrated importance	Experience and judgement <i>very strongly</i> favor one over the other. Its dominance demonstrated in practice.
8	Very, very strong	-
9	Absolutely more important	The evidence favoring one over the other is of the <i>highest possible order of affirmation</i> .
Reciprocals of above	If activity <i>i</i> has one of the above nonzero numbers assigned to it when compared with activity <i>j</i> , then <i>j</i> has the reciprocal value when compared with <i>i</i> A logical assumption	

$$w_{ij} = w_{ik} * w_{kj} \quad (1)$$

$$w_{ij} = \frac{1}{w_{ji}} \quad (2)$$

where *i*, *j*, and *k* are any alternatives of the positive reciprocal matrix.

In a perfectly consistent matrix (Equation 3), the comparisons w_{ij} are such that $w_{ij} = m_i/m_j$, where m_i is the priority of the alternative *i*.

$$A = \begin{pmatrix} m_1/m_1 & \cdots & m_1/m_j & \cdots & m_1/m_n \\ \vdots & 1 & \vdots & \cdots & \vdots \\ m_i/m_1 & \cdots & 1 & \cdots & m_i/m_n \\ \vdots & \cdots & \vdots & 1 & \vdots \\ m_n/m_1 & \cdots & m_n/m_j & \cdots & m_n/m_n \end{pmatrix} \quad (3)$$

6. Calculate the Relative Value Vector (RVV). There are several priorities derivation methods such as the eigenvalue method, the geometric mean, and the mean of normalized values. There is generally a high level of agreement between the different priorities derivation techniques (Ishizaki and Lusti, 2006:398). This research obtains the approximate principal eigenvector of the normalized matrix using the mean of normalized values method. This is based on three steps: sum the elements in column j (Equation 4); normalization of column j by dividing the comparison $w_{ij} = m_i/m_j$ by the sum of elements in column j (Equation 5); and compute the mean of row i (Equation 6) (Ishizaki and Lusti, 2006:389).

$$\frac{m_1}{m_j} + \cdots + \frac{m_i}{m_j} + \cdots + \frac{m_n}{m_j} = \frac{\sum_{i=1}^n m_i}{m_j} \quad (4)$$

$$\frac{\frac{m_i}{m_j}}{\frac{\sum_{i=1}^n m_i}{m_j}} = \frac{m_i}{m_j} * \frac{m_j}{\sum_{i=1}^n m_i} = \frac{m_i}{\sum_{i=1}^n m_i} \quad (5)$$

$$\left(\frac{m_i}{\sum_{i=1}^n m_i} + \cdots + \frac{m_i}{\sum_{i=1}^n m_i} \right) * \frac{1}{n} = \frac{n * m_i}{\sum_{i=1}^n m_i} * \frac{1}{n} = \frac{m_i}{\sum_{i=1}^n m_i} \quad (6)$$

7. Rank Order Relative Value Vector. Sum the weights in each row and rank order them based on the weighted arithmetic sum.
8. Determine Consistency. Calculate the consistency ratio (CR), shown in Equation 7, to measure how consistent the results are relative to large samples of purely random judgments.

$$CR(\mathbf{A}) = \frac{CI(\mathbf{A})}{RI_n} \quad (7)$$

$$CI(\mathbf{A}) = \frac{\lambda_{max} - n}{n - 1} \quad (8)$$

where λ_{max} is the average weighted sum of the Overall Performance Matrix.

To ensure the validity of a near consistent matrix, λ_{max} should be greater than or equal to n . The consistency index $CI(\mathbf{A})$, shown in Equation 8, should be considerably less than the RI_n from Table 3. The $CR(\mathbf{A})$ should be less than or equal to 0.10 to be acceptable else we should attempt to improve consistency. If the CR is larger than desired: 1) find the most inconsistent judgment in the Overall Performance Matrix, 2) determine the range of values to which the DM modifies the relative importance to improve consistency, and 3) ask the DM to consider changing their judgments to a value within that range. If the DM feels their judgments are accurate and the $CR(\mathbf{A})$ is still greater than or equal to 0.10, Table 4 presents Saaty's acceptable and tolerable cut-off consistency indexes by size of matrix (Wedley, 1993:153). This research uses the open-source SuperDecisions decision analysis software from Professor Saaty's Creative Decisions Foundation to aid in improving consistency (SuperDecisions, 2021).

Table 3: Random Index (Saaty, 2008:264)

Matrix Size n	Random Index (RI)
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49

Table 4: Cut-Off Consistency Indexes (Wedley, 1993:153)

	Size of Matrix					
	3	4	5	6	7	8
Acceptable (10%)	.058	.090	.112	.124	.152	.141
Tolerable (20%)	.116	.180	.224	.248	.264	.282

9. Calculate the Relative Value Vector for the Alternatives. Repeat steps 5-8 establishing priorities for the alternatives with respect to each criterion.
10. Calculate the Value for Money Vector (VMV). Establish the global priorities of the alternatives by calculating the sum-product of the RVVs calculated in step 6 (criteria weights judged against the scenario) with RVVs calculated in step 9 (alternative weights judged against each criterion). The end result is an Option Performance Matrix highlighting the preferred alternative.

3.2 Analytic Hierarchy Process Implementation

To ensure accuracy of the AHP model and the mean of normalized values method, this research utilized Microsoft Excel to verify Saaty's (1990) example in *How to Make a Decision: The Analytic Hierarchy Process* for choosing the best house to buy. An Excel template formed the foundation for a repeatable process to execute the AHP steps in Appendix A across multiple alternative futures.

3.3 Analytic Hierarchy Process Criteria

According to the JCIDS, top-level strategic and planning guidance helps to organize a framework for assessing an enormous range of operations, identify principal priorities, help set performance standards in setting criteria for the assessment, secure incontrovertible guidance, and avoid pre-disposed outcomes (CJCS, 2009:17-18). The following top-level strategic guidance was considered in this research. It provides criteria that articulate characteristics of air mobility supporting the Joint Force's ability to move and maneuver:

- JP 4-0, *Joint Logistics*, is the foundational document of the Joint logistics series and provides the logistician with fundamental guidance for planning, execution, and assessment of joint operations (CJCS, 2019b:i).
- JP 3-17, *Air Mobility Operations*, provides the air mobility enterprise with fundamental principles to plan, employ, and assess air mobility operations across the continuum of joint operations (CJCS, 2019a:i).

- AFDP 3-36, *Air Mobility Operations*, is a collection of lessons learned and best practices ranging from airlift operations in World War II to most recent operations countering violent extremist organizations (USAF, 2019: 1).
- The Model of Air Mobility Utility from *Behind the Light Switch: Toward a Theory of Air Mobility* offers a one-stop shop of key factors that deliver a theory of air mobility for planners and policy makers to analyze the value of air mobility operations (Salmi, 2020:ix).
- The Table of Modality Decision Criteria from *Sealift or Airlift for Global Mobility* offers quantitative and qualitative factors that the USTRANSCOM enterprise must consider as the Joint Force's primary strategic lift provider (Prevett and Anderson, 2007:3-5; Prevett and Anderson, 2017:16).
- *Algebra of Airlift* and AFPAM 10-1403, *Air Mobility Planning Factors*, provide logisticians the fundamental algebraic relationships to make gross estimates about air mobility requirements during the planning process (Brigantic and Merrill, 2004:649; USAF, 2018:1).

As it relates to agile PTP logistics, the air mobility criteria listed in Appendix B are applicable to space mobility with exception to variables directly involving aircrews and passengers such as medical, stage crews, and crew ratios. A vast majority of these criteria are areas of investigation in the USAF Vanguard's various lines of effort. Table 5 highlights the interactions between the JP 4-0 Principles of Logistics and the air mobility criteria identified in JP 3-17, AFDP 3-36, Model of Air Mobility Utility, Table of Modality Decision Criteria, Algebra of Airlift, and AFPAM 10-1403.

Table 5: Top-Level Strategic Guidance Interaction (Brigantic and Merrill, 2004:649-656; CJCS, 2019a:III-1-20; CJCS, 2019b:I-8-9; Prevett and Anderson, 2017:16; Salmi, 2020:2-23; USAF, 2018:1-36; USAF, 2019:30-34)

	JP 4-0	JP 3-17	AFDP 3-36	Air Mobility Utility Model	Table of Modality Decision Criteria	Algebra of Airlift and AFPAM 10-1403
Responsiveness	●			●	●	●
Simplicity	●	●	●	●	●	
Flexibility	●		●	●	●	
Economy	●				●	●
Attainability	●	●	●	●	●	●
Sustainability	●	●	●	●	●	●
Survivability	●	●	●	●	●	

The JP 4-0 Principles of Logistics factors of responsiveness, simplicity, flexibility, economy, attainability, sustainability, and survivability serve as primary criteria for evaluating alternatives in this research and are pertinent factors for a Combatant Commander to consider regardless of mode choice.

3.3.1 Responsiveness

Responsiveness is providing the Joint Force the support it needs when and where it is required. Velocity (or block speed), displacement (or round-trip flying time), time to arrival (or active route flying and ground time), reliability (or mission capable rate), productivity, and anticipation of warfighter requirements are key characteristics of responsiveness (Brigantic and Merrill, 2004:650; CJCS, 2019b:I-8; Prevett and Anderson, 2017:12; Salmi, 2020:3; USAF, 2018:1,14-15). Table 6 approximates capacity and velocity capabilities of each aircraft and spacecraft with respect to a notional trip from Travis AFB, CA (KSUU) to Wake Island (PWAK). In terms of capacity, the C-5M is comparable to the Starship while the C-17A is comparable to the New Glenn; strategic

airlift capacity over long distances can increase with aerial refueling. In terms of velocity, the C-5M and C-17A have similar cruising speeds while the Starship and New Glenn are conceptually feasible to arrive PTP anywhere on earth in approximately 45 minutes with a resulting velocity of approximately 6,000 nautical miles per hour (knots).

Table 6: Approximate Capacity and Velocity Capabilities of C-5M, C-17A, Starship, and New Glenn from Travis AFB, CA (KSUU) to Wake Island (PWAK) (Airlift App, 2021; “New Glenn Payload User’s Guide Revision C,” 2018:57; “Starship Update,” 2022; “Starship Users Guide Revision 1.0,” 2020:2; USAF, 2018:16)

Characteristic	C-5M	C-17A	Starship	New Glenn
Capacity (metric tons/lbs)	72.2 / 159,173	36.9 / 81,350	100 / 220,462†	45 / 99,208
Velocity (nm/hr or knots)	415	405	5,988	5,988
Distance (nautical miles)*	4,491	4,491	4,491	4,491
Time (hr+min)	10+49	11+05	0+45	0+45
Productivity (9)**	0.49	0.49	0.099	0.099

* = Distance is standardized across all platforms. Velocity is calculated using Distance ÷ Time.

**Spacelift productivity assumes a worst-case scenario to pre-position materiel from KSUU (Travis AFB) to KXMR (Cape Canaveral Space Force Station) (2,463 nm).

† SpaceX has projected a Starship capacity of 150 metric tons to low earth orbit; this research assumes 100 metric tons due to likely volume limitations in the Starship payload fairing.

Aerial refueling will be limited to strike and air superiority aircraft in a major conflict therefore airlift platforms will most likely require enroute stops increasing its total round trip flying time. Spacelift platforms are designed to be autonomous and are not bound by crew rest requirements which consume at least 12 hours in a mission’s sequence of events assuming the mission authority adequately postures aircrew. However, potentially increased ground times can negate spacelift’s autonomous and uncrewed advantages. In terms of readiness, the C-17A has a reliability advantage over the C-5M with higher mission capable rates (GAO, 2020:70-77). SpaceX has exhibited as of 2017 a 98% launch success rate for its Falcon 9 rocket while Blue Origin has had 19 successful consecutive missions using its New Shepard rocket (“Blue Origin Record of

Safety,” 2022; FAA, 2018:43). With respect to efficiency, the productivity Equation 9 from *Air Mobility Planning Factors* results in lower productivity with increasing round trip flying time and origin to onload flying time, or load efficiency. Airlift will experience lower productivity due to its requirement to make enroute stops over long distances increasing round trip flying time and spacelift will experience lower productivity because of greater origin to onload flying time due to fewer spaceports with co-located aerial ports and more intensive cargo pre-positioning requirements (Magidson, 2022).

$$Productivity = \frac{(One\ Way\ Enroute\ Flying\ Time)}{(Round\ Trip\ Flying\ Time) + (Origin\ to\ Onload\ Flying\ Time)} \quad (9)$$

Spaceports will be far more limited in number than airports due to operators preferring to locate launch sites near the equator to take advantage of added inertia and requiring more open launch airspace to the east to take advantage of Earth’s orbit. Airlift has the organic capability to pre-position itself to the aerial port of embarkation which gives it an advantage over spacelift in origin to onload flying time; since spacelift does not have this organic capability, it will consume additional airlift resources to pre-position cargo. Productivity could be increased for spacelift by having platforms in an alert posture on the ground with critical materiel pre-positioned in unit configurations to aid in rapid movement; highly specialized payloads could also be pre-positioned in a geostationary fractional orbit to truly leverage spacelift’s unique capabilities.

3.3.2 Simplicity

Simplicity reduces the friction, or fog of war, of combat with efficiency in planning and execution of logistics operations. Contributing to simplicity are clarity of

objectives (or higher headquarters taskings), synchronized and standardized command and control procedures and processes, unity of effort through clearly defined command relationships, efficient multinational planning considerations, and constant custody and in-transit visibility of enroute cargo. Detracting from simplicity are late system requests characterized with little to no advance notice in the time phased force deployment data (TPFDD) execution, inflated requirements, additional joint inspection constraints, emerging requirements with varying criticality, and lengthy diplomatic clearance approval timelines from partner nations (CJCS, 2019a:x,xii,I-15; CJCS, 2019b:I-8; Prevett and Anderson, 2017:12; Salmi, 2020:9; USAF, 2019:31).

Airlift is simpler than spacelift if there are multiple detractors driving greater origin to onload flying time due to late system requests and scarcity of materiel availability near spaceports. On the contrary, the PTP capability of spacelift could be viewed as increasing simplicity due to a lower reliance on the enroute mobility system. In terms of policy and law issues, spacelift's trajectory and re-entry profile (Figure 11) has the potential to reduce the number of overflight diplomatic clearances required from partner nations due to a majority of flight taking place in typically uncontrolled airspace above 60,000 feet (18.28 kilometers). On the contrary, diplomatic clearance approval timelines could be aggravated should the United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space levy additional restrictions on PTP spacelift. Constant custody and in-transit visibility of PTP spacelift cargo will contribute to a greater unity of effort through a more streamlined command and control process.

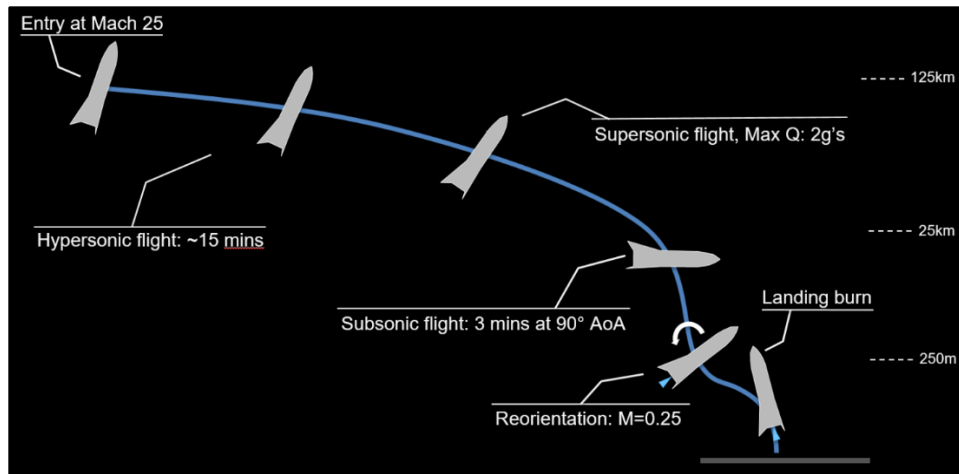


Figure 11: SpaceX Starship Re-Entry Trajectory (“Starship Update 2.0,” 2022)

3.3.3 Flexibility

Flexibility is the ability to pivot logistics requirements and procedures to evolving missions and operational requirements. Responding precisely to unanticipated changes in dynamic environments and delivering diverse support tools to the warfighter are characteristics of flexibility. The mobility force’s capacity to rapidly aggregate, disaggregate, and re-aggregate the Joint Force across the full spectrum of locations with logistics under attack is representative of a high degree of flexibility. Technology, integrated logistics, diverse support options, training, and system knowledge enable a Combatant Commander to be flexible (CJCS, 2019b:I-8-9; Prevett and Anderson, 2017:12; Salmi, 2020:13-17; USAF, 2019:31).

This research assumes that aircraft will be more flexible than spacecraft in the preparation phase prior to flight until RDT&E develops novel loadmaster designs to enable loading and unloading of a rocket on timelines comparable to airlift. Spacelift’s responsiveness can be a detriment to its flexibility since it does not have the capability to

respond to unanticipated changes once the rocket has been launched whereas airlift can be diverted even after it has arrived overhead its original destination. On the contrary, spacelift may simply not require this flexibility because of its far shorter time to arrival. Landing zone availability and environmental suitability could also constrain spacelift's flexibility although highly specialized payloads positioned in geostationary orbit could increase flexibility. Spacelift will most likely require a launch and catch tower arm at the landing zone to expedite cargo offload and launch reconstitution; reliance on spaceports makes spacelift less flexible. The C-17A remains one of the most flexible airlift platforms in the world with the ability to operate on semi-prepared runways; the C-5M has the capability but has not been utilized in that capacity for some time.

3.3.4 Economy

Economy is the fewest amount of personnel and materiel to achieve a specific mission within acceptable levels of risk. Reducing redundancy in operations to minimize the cost per pound of payload of the fleet is a critical element of the logistics principle of economy (Brigantic and Merrill, 2004:654; CJCS, 2019b:I-8; Prevett and Anderson, 2017:16; USAF, 2018:2). Koether (2018:26-29) provides a cost per pound of payload calculation. Maywald and others (2017:67) provide a cost per flying hour logistics cost planning factor. AMC (2021:10) provides rates for SAAM and contingency missions for the Transportation Working Capital Fund (TWCF).

Fully commercialized PTP spacelift with regular rocket reusability and a high frequency of launches can significantly reduce the cost per pound of payload by up to five to 20 orders of magnitude (Figure 2). Spacelift may be the lowest cost means of

transporting cargo over long distances in terms of capital efficiency provided that propellant costs are competitive with jet fuel; a rocket’s velocity allows it to be reused approximately 12 times more often than an aircraft in a 24-hour period (“Starship Update,” 2022). A Civil Reserve Space Fleet with extensive commercial spaceport infrastructure would significantly reduce infrastructure costs for the DoD. An added consideration to the criterion of economy is the added cost and end-to-end time considerations of recovering a rocket from its landing zone; commercial spacelift providers should aim to make the recovery cost proportional to airlift’s inactive (return leg) flying hour costs. Scenarios requiring spacelift’s velocity advantage will most likely relegate the criteria of economy due to a Combatant Commander’s calculation of acceptable risk.

3.3.5 Attainability

Attainability is the point in time at which the Joint Force has the required initial materiel and support capacity to commence operations at an acceptable level of risk. Responsiveness (or velocity) and capacity must surpass the area of mission vulnerability to achieve attainability (Figure 12). The million ton-miles per day (MTM/D), shown in Equation 10, quantifies capacity as a simple aggregate metric that reflects the unconstrained capacity to move cargo in a distance during a timeframe with a given fleet of vehicles (Brigantic and Merrill, 2004:654; USAF, 2018:2).

$$\frac{MTM}{Day} = \frac{(\#Acft) * (Block\ Speed) * (Avg\ Payload) * (UTE\ Rate) * Productivity}{1,000,000} \quad (10)$$

*Block Speed, Avg Payload, UTE Rate, and Productivity assumptions listed in AFPAM 10-1403.

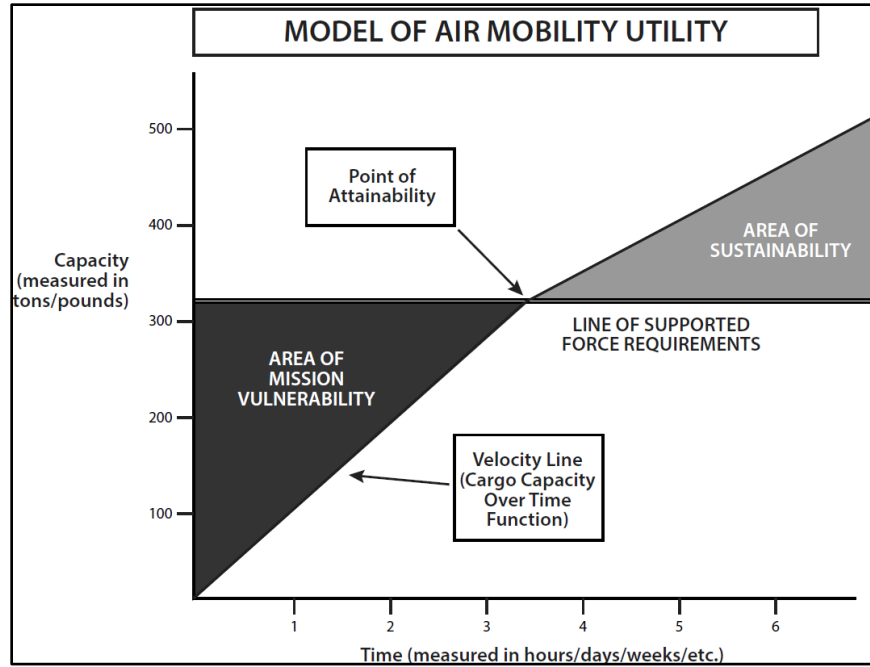


Figure 12: Model of Air Mobility Utility (Salmi, 2020:4)

USTRANSCOM has historically utilized the metric of 33.95 MTM/D as a foundation for organic airlift programming and budgeting decisions and strategic airlift acquisition advocacy (Merrill, 2013). While spacelift can offer greater million ton-miles per day capacity with 14-15 times greater block speed over aircraft, this factor is offset by a greater number of airlift assets and airlift's higher productivity rate with probable lesser origin to onload flying time. The fleet capability short tons delivered to the theater per day (FCD/D), shown in Equation 11, is preferred for contingency planning because it more accurately models the deployment of requirements (USAF, 2018:2).

$$\frac{FCD}{Day} = \frac{(\#Acft) * (Avg Payload) * (UTE Rate)}{(Round Trip Flying Time)} \quad (11)$$

*Avg Payload and UTE Rate assumptions listed in AFPAM 10-1403.

The greater number of airlift assets and higher UTE rates currently gives airlift the advantage in the FCD/D metric. This advantage will persist until the commercial space industry normalizes the reusability of boosters and payload fairings. The C-17A has an advantage over the C-5M in delivering an operation's initial minimal requirements through its airdrop capability. Key factors precluding attainability are low platform reliability (or mission capable rate), TPFDD execution inefficiency, and GAMSS inefficiency (Brigantic and Merrill, 2004:654; CJCS, 2019a:III-13; CJCS, 2019b:I-8-9; Prevett and Anderson, 2017:16; Salmi, 2020:4; USAF, 2018:2; USAF, 2019:30-32). Spacelift platforms are highly susceptible to scrubbed launches due to inclement weather, high winds, cold temperatures, technical abnormalities, and factors penetrating range safety.

3.3.6 Sustainability

Sustainability is when the materiel and support capacity requirements of the supported force are at the necessary level to achieve long-term military objectives at an acceptable level of risk. When attainability is achieved, responsiveness and capacity transition into the area of sustainability (Figure 12). The number of missions required to deliver an operation's necessary cargo is represented in Equation 12 (USAF, 2018:1).

$$Number\ of\ Missions\ Required = \frac{(Requirement)}{(Avg\ Payload)} \quad (12)$$

Table 6 shows a comparable advantage in payload capacity for the Starship and New Glenn when compared with the C-5M and C-17A leading to a lower number of missions required, however, space mobility's high costs may negate this advantage. The

number of days required to complete a mission given a fleet of aircraft is represented by *Air Mobility Planning* Factors in Equation 13.

$$Closure = \frac{(Requirement) * (Round Trip Flying Time)}{(Avg Payload) * (\#Acft) * (UTE Rate)} \quad (13)$$

With closure, spacelift has an advantage with a far lower round trip flying time. For the Starship and New Glenn to retain this closure advantage, spacelift ground times must at least be similar to airlift's combined crew rest requirements and round-trip flying time to include enroute stops. Key factors of long-term sustainability include economy, location of sustainment operations (airports and spaceports), GAMSS base operating support, and station interval (station ground time vs. station capability) (Brigantic and Merrill, 2004:651,655; CJCS, 2019a:xi-xii; CJCS, 2019b:I-9; Prevett and Anderson, 2017:16; Salmi, 2020:2; USAF, 2018:26; USAF, 2019:33).

3.3.7 Survivability

Survivability is the capacity of the sustainment force to maintain freedom of maneuver against specific vulnerabilities and threats. Logistics under attack is a key operational challenge against a learning, near-peer adversary (Berry, 2020). The increasingly wide proliferation of adversarial anti-access and area-denial capabilities pose grave risks to current airlift platforms; spacelift platforms will not be immune to these risks. An attack in the cyber domain could provide an adversary significant advance notice of and closely track an extensive airlift operation; a spacelift platform's greater velocity and uncrewed nature could provide an advantage in reducing an adversary's decision space.

While spacelift's PTP capability conceivably allows it to land closer to forces being sustained, it is potentially as vulnerable to surface to air and surface to surface weapons as any airlift platform. Spacelift's potentially rapid reconstitution timelines while on the ground could alleviate surface to surface threats. Mitigating these threats is crucial to sustaining critical logistics infrastructure and providing the Joint Force with continuity of support (CJCS, 2019a:x-xi; CJCS, 2019b:I-9; Prevett and Anderson, 2017:16; Salmi, 2020:6; USAF, 2019:32-34).

3.4 Analytic Hierarchy Process Alternatives

The DM uses the seven criteria of the JP 4-0 Principles of Logistics to evaluate the C-5M, C-17A, Starship, and New Glenn.

Lockheed Martin's C-5M Super Galaxy and Boeing's C-17A Globemaster III are the USAF's primary strategic airlift platforms. Table 7 lists general characteristics for both aircraft. The first operational C-5A arrived at Charleston AFB, South Carolina in June 1970. The C-5B upgrade resulted in several systems modifications in the late 1980s and included the procurement of two space cargo modified C-5Cs. The C-5 Avionics Modernization Program (AMP) and Reliability Enhancement and Re-engineering Program (RERP) modifications culminated in today's C-5M fleet of 52 aircraft. AMP upgraded the C-5's avionics while RERP upgraded the C-5's engines delivering a 22 percent thrust increase, a 30 percent shorter take-off roll, and a 58 percent faster climb rate. The C-5 has served in all major conflicts since Vietnam ("C-5M Super Galaxy," 2021). The first operational C-17A arrived at Charleston AFB, South Carolina in June 1993. The C-17A can deliver troops and cargo to main operating bases, directly to austere

forward bases in the deployment area, or via airdrop. The C-17 differentiates itself from the C-5 in that it can airdrop troops and/or cargo and land on austere or semi-prepared airfields. The C-17A has served in all major conflicts since the 1990s (“C-17 Globemaster III,” 2020).

Table 7: Specifications of C-5M and C-17A (AMC, 2021:10; “C-17 Globemaster III,” 2020; “C-5M Super Galaxy,” 2021; USAF, 2018:15-16)

Characteristic	C-5M	C-17A
Crew (Typical)	7 (aircraft commander, first pilot, 2 flight engineers, 3 loadmasters)	3 (aircraft commander, first pilot, 1 loadmaster)
Pallet Positions (463L)	36	18
Max Takeoff Weight (lbs)	840,000	585,000
Range (nm)	4,800 w/120,000 lb payload	2,420 w/157,000 payload
Ferry Range (no cargo) (nm)	7,000	4,300
Onload/Offload Ground Time	3+45	2+45
Primary Mission Aircraft Inventory	48	188
SAAM Contingency Flying Hour Rate (\$)	33,054	16,190

SpaceX’s Starship and Blue Origin’s New Glenn are currently the most advanced rockets with fully reusable first stage boosters. SpaceX and Blue Origin project the capability to recover both the first and second stage boosters of the Starship and New Glenn. Table 1 lists general characteristics for both spacecraft. Elon Musk founded SpaceX in 2002 to enable regular access to space and to empower a multi-planetary society. SpaceX performs routine missions today with its Falcon 9 and Falcon Heavy launch vehicles for customers like the DoD, the National Aeronautics and Space Administration (NASA), and the National Reconnaissance Office (NRO). SpaceX’s Starship represents a fully reusable strategic lift platform designed to service low earth orbit needs as well as missions to Mars (“Starship Users Guide Revision 1.0,” 2020).

SpaceX's launch and catch tower arm in development will be a crucial capability for use in rapid onload and offload of PTP spacelift cargo. Jeff Bezos founded Blue Origin in 2000 to make space access more affordable and reliable through reusable spacecraft. Blue Origin launched its first crewed mission into space via its New Shepard rocket in July 2021. New Glenn represents a high-performance space launch system to deliver equipment to low earth orbit and geostationary transfer orbit with potential dual manifest capability ("New Glenn Payload User's Guide Revision C," 2018). The New Glenn platform is assumed to be more affordable in total cost than the Starship due to its smaller payload capacity and reduced infrastructure requirements. Both spacelift platforms should be comparable in total cost per pound of payload.

3.5 Analytic Hierarchy Process Network Structure

The AHP models a decision using a hierarchic or network structure to characterize a problem and pairwise comparisons to build relationships within the structure. The hierarchy must be complex enough to capture the situation but must also be concise enough to be sensitive to changes (Saaty, 1987:163). The hierarchy does not need to be fully comprehensive in that an element in any given level does not have to function as an attribute for all the elements in the level below (Saaty, 1990:9). An AHP hierarchy is not a traditional decision tree and each level may represent varying factors where a decision maker can add or remove levels and elements as necessary to clarify the setting of priorities. It is a requirement that the criteria, or the characteristics compared, and the alternatives are "gradually layered in the hierarchy so that it is meaningful to compare them among themselves in relation to the elements of the next higher level"

(Saaty, 1990:10). Figure 13 represents the AHP hierarchy for this research. The goal is a statement of the overall priority, the criteria are objectives needing consideration, and the alternatives are available to satisfy the goal.

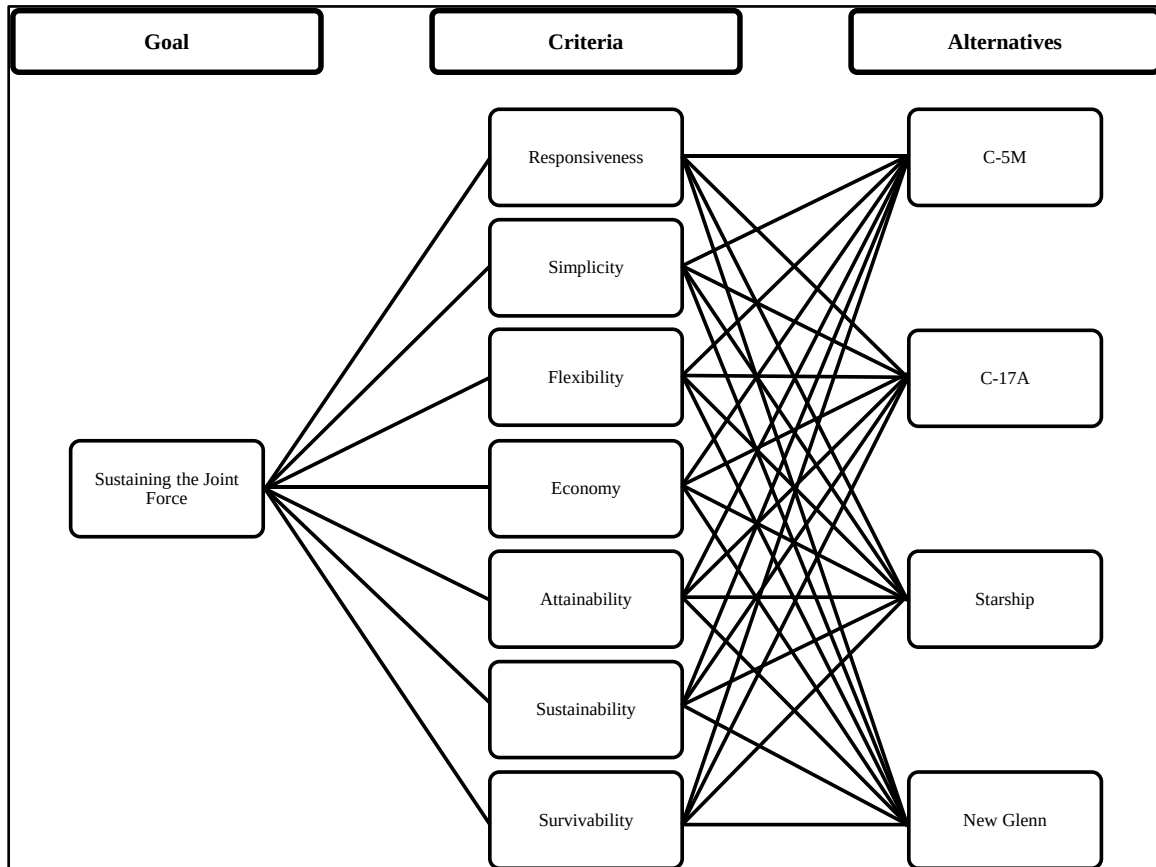


Figure 13: AHP Hierarchy

3.6 Analytic Hierarchy Process Alternative Futures

Scenarios provide the DM significant context in judging the importance of criteria and the utility of alternatives. The DoD's Capabilities-Based Assessments provide CJCS guidance to test capabilities against various operating conditions and defines scenarios as providing the depth and breadth of the environments considered. Scenarios are important as they provide: the means to assess the capabilities associated with the mission area, a way to connect the assessment topic to the existing strategic guidance, and a way to test the concept against the breadth of the defense strategy and the spectrum of conditions considered (CJCS, 2009:37). Real-world CBAs will typically use scenarios that are based on classified operational and contingency plans as well as Defense Planning Scenarios (CJCS, 2009:29).

Parnell and others (1999:3) use alternative futures in their decision analysis methodology to examine research and development concepts to potentially deploy as future USAF weapon systems. Jackson and others (1996:36-37) utilize the concept of alternative futures to objectively identify valuable system concepts and enabling technologies that show the greatest capacity to enhance air and space superiority. Sotiriadis and Grove (2020:2) use alternative futures to stress the importance of cultivating strategic foresight and anticipatory thinking to aid decision-making in the DoD.

This research will develop six fictional alternative futures that are loosely based on the challenges outlined in the 2018 National Defense Strategy, 2021 Interim National Security Strategic Guidance, and the Air Force Warfighting Integration Capability Global Futures Report (OSD, 2018; The White House, 2021; Sotiriadis and Grove, 2020). Each

alternative future represents varying points on the vulnerability to point of attainability to sustainability continuum presented in the Model of Air Mobility Utility (Figure 12).

Three of the alternative futures are based on situations in the Indo-Pacific and three are based in Europe. In this research, the DM made pairwise comparisons among AHP primary criteria and strategic lift platforms, in the context of the following alternative futures.

3.6.1 Alternative Future Indo-Pacific 2030

The People's Republic of Xuesen (PRX) has begun its invasion of Lindgren, its neighboring island nation. The country of Goddard, backed up by its coalition of allies, launches seven B-147 nuclear-capable bombers on a non-stop global strike mission rendezvousing just east of the second island chain with multiple air refueling tankers and a squadron's equivalent of F-93 fighter jets based at Oberth Air and Space Force Base (ASFB). The PRX views this as a direct threat to its operation in the first island chain and directs its Rocket Force to conduct precision strikes on Goddard's outposts in the Pacific, Oberth and Kranz ASFB. The PRX 62X Brigade launches its OB-17 from Base 62. A PRX hypersonic glide vehicle separates from the OB-17 and damages key infrastructure at Oberth and Kranz. Oberth ASFB degrades to a single operating runway and apron with multiple damaged taxiways. The PRX renders Kranz ASFB and all other allied bases within the first island chain completely inoperable. The PRX threatens additional attacks to deter Goddard from further military actions. Oberth ASFB requires the rapid delivery of multiple 3-D concrete printer robotic arms, ground-based augmentation system antennas to restore basic airport functionality, and a Deployable Air Base System to restore command and control functions. The equipment has passed joint inspection for all

strategic lift platforms and are widely available across Goddard's defense supply chain. Standard special operations air mobility alert crews and aircraft are available. Operational support requirements at Oberth ASFB continue to fluctuate as the situation develops.

3.6.2 Alternative Future Indo-Pacific 2035

A border dispute at the Line of Actual Control between the Republic of Dhawan and the PRX has rapidly developed into a wider regional conflict encompassing the greater Indo-Pacific. The Quadrilateral Security Dialogue, or the Quad, comprising the countries of Goddard, Dhawan, Akiyama, and the Commonwealth of Chapman begin a naval blockade of PRX. The Quad stages troops and materiel on the strategic island bases of Sarabhai ASFB, Menon ASFB, Sharma AFB, and Chawla AFB just west of the main shipping lane between the Indian and Pacific oceans effectively creating a naval iron curtain. The Quad intends to deny over eighty percent of the PRX's hydrocarbon resources from passing through this vital shipping lane. The situation creates a stalemate between the Quad and PRX navies with resupply of island bases a persistent challenge. The PRX's A2/AD threats pose a significant logistics challenge to the Quad whose forward deployed forces are in need of basic sustainment supplies. The PRX has further complicated the sustainment of Quad basing with use of its shadow navy, civilian merchant ships and fishing vessels, to launch surprise attacks on Dhawan island bases as well as the military ports of Akiyama and Chapman. This strategy forces the Quad to execute an agile and anticipatory operational scheme of tactical maneuver executed expeditiously to increase the survivability of its Joint Forces while generating combat power. Operationally, the Quad nations field a significant advantage in MQ-175 boom-capable autonomous aerial refueling drones able to project rapid global mobility with

increased freedom of maneuver. With energy resources for its military rapidly declining 90 days after the start of the conflict, the PRX is expected to sign a peace treaty with Dhawan and its Quad partners.

3.6.3 Alternative Future Indo-Pacific 2040

Initial assessments following a magnitude nine earthquake along Akiyama's Trench shows extensive damage especially in its capital Yamazaki. 180,000 people have perished in the Akiyama prefectures of Mukai, Wakata, Doi, and Yamazaki with the death toll expected to rapidly increase. Approximately 195,000 buildings are estimated to be destroyed with potential economic fallout for the region and the country to be north of a quarter trillion dollars. Much of the building damage was caused by a tsunami which also caused over two million people to flee to higher ground requiring rescue. Goddard initiates extensive humanitarian assistance and disaster relief (HA/DR) operations with support from the United Nations. Akiyama requires the movement of 37,500 short tons of humanitarian supplies including food, water, and outsized rolling stock comprising water filtration systems, temporary housing trailers, all-terrain vehicles, rescue helicopters, rescue boats, and cranes, among many others. Goddard's Secretary of Defense has ordered the Commander of Transportation Command to activate Stage I of both the CRAF and the CRSF to provide commercial air and space resources to augment organic airlift capacity. The CRSF includes six commercial rocket companies that collectively launch over 600 terrestrial PTP cargo sorties a year. Due to the distance to Akiyama, the C-17A will require a 1+45 ground refueling quick turn stop.

3.6.4 Alternative Future Europe 2030

After almost two decades of Intensified Dialogue and significant progress in their Membership Action Plans, the countries of Kadenyuk and Yurchikhin are formally accepted into the North Atlantic Military Alliance (NAMA). Kadenyuk and Yurchikhin have overcome many years of conflict with the country of Korolev as it continuously inflamed ethnic territorial disputes and sought to undermine economic stability. A 2022 conflict in eastern Kadenyuk with Korolev, characterized by hybrid warfare, led to five years of debilitating economic sanctions on Korolev by NAMA states. This led to the plummeting of Korolev's gross domestic product from a high of 2.29 trillion dollars to just over one trillion mostly due to drastically reduced energy exports. The addition of two new member countries to NAMA followed by the addition of three Scandinavian states (Kopra, Nyberg, and Fuglesang) four years prior in 2026 serve as red lines for Korolev. Thousands of Korolevian-speaking expatriates begin fomenting violent dissent in NAMA's Baltic states as well as in Kadenyuk and Yurchikhin. Korolev releases an unprecedented malware cyber-attack on NAMA countries severely crippling the alliance's critical infrastructure with natural gas supply from Korolev to Europe decreasing from 40% to 15% of its total. Goddard mobilizes its Joint Force to execute its Article 5 mutual defense obligations. Goddard's Secretary of Defense aims to expedite TPFDD closure and deploy several Deployable Air Base Systems (DABS) to NAMA allies. The commander of Goddard's Transportation Command activates Stage I of the CRAF to provide commercial air resources to augment organic airlift capacity. Commercial space resources are available but legislation to approve the CRSF is bogged down in a filibuster in Goddard's Senate; however, there are two dozen Starship's and

New Glenn's available on alert posture. As Goddard's materiel and support capacity flow to NAMA's eastern flank, Korolev continues its march westward.

3.6.5 Alternative Future Europe 2035

The unforgiving extreme cold conditions of the Arctic have largely detracted countries from any full-blown conflict in that region. With early twenty-first century warnings of the polar ice caps melting becoming a reality, geopolitical rivalries begin to escalate. Korolev has increased its maritime patrols tenfold compared to the previous decade to protect its newfound oil reserves. The PRX has also made significant investments in hydrocarbon harvesting infrastructure in the region and has warned Goddard and the NAMA nations to remain outside of its self-imposed exclusive economic zones. Goddard, in an effort to safeguard the world's access and exploration of the Arctic, continues to ramp up its freedom of navigation operations (FONOPS). The Goddard Navy regularly sails just outside 12 nautical miles of Korolev and PRX's outposts, the Air Force routinely conducts intelligence, surveillance, and reconnaissance (ISR) missions, and the Space Force routinely lands Rocket Cargo for resupply on Nyberg's Arctic islands. During a routine Goddard ISR mission, an RQ-920 uncrewed aerial vehicle sets up orbit just outside a Korolev base, Gagarin, to collect intelligence on recently transferred integrated air defense systems. Screens at a Goddard Ground Control Station go blank as the RQ-920 is engaged by a Korolev short-range SA-1200. Tensions are heightened as Korolev and PRX effectively blockade the Northern Sea Route resulting in a significant drop in international trade along the Arctic passage. This poses a significant economic threat to NAMA nations as a majority of trade routes from Asia have transitioned to the Northern Sea Route. In an effort to deny Korolev and PRX's

blockade of the Northern Sea Route, Goddard and NAMA execute a surge in FONOPS. Nyberg, part of the NAMA alliance, requests long-term sustainment assistance from Goddard for several of its Arctic archipelagos that serve as allied resupply bases. Several spacelift platforms are available on alert and the CRSF is available to be activated to Stage I should it be required to meet Arctic Command's theater needs. The same number of C-5M and C-17A aircraft are available to the Combatant Commander.

3.6.6 Alternative Future Europe 2040

At 9:40pm local time on January 3, 2040, members of a militant group attack the Goddard diplomatic compound in Tereshkova, the capital city of Leonov, a fledgling democracy south of Korolev. Two diplomatic team members are killed and three clandestine service agents are wounded in the mortar attack. The Diplomatic Security Group and the Marine Corps Embassy Security Service successfully suppress the startling attack. Intelligence suggests that the attack arose from country-wide protests fueled by a video on the metaverse released to coincide with the 20th death anniversary of the militant group's leader. Further intelligence reveals that a larger protest is being organized to arrive at the compound in approximately six hours with a high probability of further violent attacks. The compound's internal security deems their current resources to be insufficient in repelling any larger and sustained attacks. A request is made to Goddard's Diplomatic Security Group Command Center for a Marine Quick Reaction Force to reinforce compound defense. The closest available reinforcement options with associated airlift are at Maurer ASFB with C-130Js on alert but they require eight hours of flight time in addition to ground vehicle transition time from the landing airfield to the diplomatic compound. Several spacelift platforms and C-17A crews are available on alert

from continental Goddard; both spacelift platforms and the C-17A have airdrop capability. There is a helicopter landing pad, measuring 80 yards wide and 120 yards long, at the Goddard diplomatic compound that can be used as an ingress area.

3.7 Data Description and Analysis

3.7.1 Alternative Future Indo-Pacific 2030

Overall Preference Matrix								
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	
Responsiveness	1	4	5	9	7	8	2	
Simplicity	1/4	1	2	5	3	4	1/2	
Flexibility	1/5	1/2	1	4	2	3	1/3	
Economy	1/9	1/5	1/4	1	1/3	1/2	1/8	
Attainability	1/7	1/3	1/2	3	1	2	1/6	
Sustainability	1/8	1/4	1/3	2	1/2	1	1/7	
Survivability	1/2	2	3	8	6	7	1	
Sum	2.329	8.283	12.083	32.000	19.833	25.500	4.268	
Normalization								
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	RVV (Crit)
Responsiveness	0.429	0.483	0.414	0.281	0.353	0.314	0.469	0.392
Simplicity	0.107	0.121	0.166	0.156	0.151	0.157	0.117	0.139
Flexibility	0.086	0.060	0.083	0.125	0.101	0.118	0.078	0.093
Economy	0.048	0.024	0.021	0.031	0.017	0.020	0.029	0.027
Attainability	0.061	0.040	0.041	0.094	0.050	0.078	0.039	0.058
Sustainability	0.054	0.030	0.028	0.063	0.025	0.039	0.033	0.039
Survivability	0.215	0.241	0.248	0.250	0.303	0.275	0.234	0.252
								1.000
Consistency								
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	λ max
Responsiveness	0.392	0.557	0.465	0.244	0.405	0.311	0.505	7.177
Simplicity	0.098	0.139	0.186	0.135	0.173	0.155	0.126	
Flexibility	0.078	0.070	0.093	0.108	0.116	0.117	0.084	
Economy	0.044	0.028	0.023	0.027	0.019	0.019	0.032	CI
Attainability	0.056	0.046	0.046	0.081	0.058	0.078	0.042	0.029
Sustainability	0.049	0.035	0.031	0.054	0.029	0.039	0.036	
Survivability	0.196	0.279	0.279	0.217	0.347	0.272	0.252	CR
								0.022

Figure 14: Alternative Future Indo-Pacific 2030 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: responsiveness, survivability, simplicity, and flexibility. Responsiveness is the most critical criterion due to Oberth ASFB requiring a rapid restoration of mission capability. Survivability is essential due to the PRX's persistent threats in the theater of operations. Simplicity is a necessary consideration with the varying criticality of emerging requirements on the airfield. Flexibility is desirable due to Oberth ASFB's single runway operation and a generally degraded airfield. The criteria of attainability, sustainability, and economy are insignificant in this alternative future. The DM's judgments were highly consistent at 0.022.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/2	1/8	1/5	
C-17A	2	1	1/9	1/6	
Starship	8	9	1	2	
New Glenn	5	6	1/2	1	
Sum	16.000	16.500	1.736	3.367	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.063	0.030	0.072	0.059	0.056
C-17A	0.125	0.061	0.064	0.050	0.075
Starship	0.500	0.545	0.576	0.594	0.554
New Glenn	0.313	0.364	0.288	0.297	0.315
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.056	0.037	0.069	0.063	4.101
C-17A	0.112	0.075	0.062	0.053	CI
Starship	0.448	0.673	0.554	0.631	0.034
New Glenn	0.280	0.449	0.277	0.315	CR
					0.038

Figure 15: Alternative Future Indo-Pacific 2030 - OPM (Responsiveness)

The DM found responsiveness to be the most critical criterion in this alternative future and ranked the Starship as the top alternative to provide the Joint Force the support it needs to quickly restore loss of mission capability at Oberth ASFB. The DM valued the Starship's responsiveness over the New Glenn due to its higher capacity and ability to deliver all materiel in one sortie. The DM valued the two strategic spacelift platforms far more than the two strategic airlift platforms due to the productivity (9) overmatch and the resultant ability to more rapidly restore Oberth ASFB. The required equipment's availability across the DoD supply chain negates the typical origin to onload flying time advantage for airlift assets. In addition, the two strategic spacelift options do not require crew rest in the mission's sequence of events leading to greater responsiveness. The DM's judgments were highly consistent at 0.038.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	1/7	1/8	
C-17A	3	1	1/4	1/5	
Starship	7	4	1	1/2	
New Glenn	8	5	2	1	
Sum	19.000	10.333	3.393	1.825	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.053	0.032	0.042	0.068	0.049
C-17A	0.158	0.097	0.074	0.110	0.109
Starship	0.368	0.387	0.295	0.274	0.331
New Glenn	0.421	0.484	0.589	0.548	0.511
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.049	0.036	0.047	0.064	4.078
C-17A	0.147	0.109	0.083	0.102	CI
Starship	0.342	0.438	0.331	0.255	0.026
New Glenn	0.391	0.547	0.662	0.511	CR
					0.029

Figure 16: Alternative Future Indo-Pacific 2030 - OPM (Survivability)

The DM judged survivability to be an essential priority in this alternative future and ranked the New Glenn above the Starship and the two strategic airlift platforms. Persistent enemy threats and continuously challenging Pacific weather patterns were significant considerations in this alternative future. The spacelift platforms offered greater freedom of maneuver and resiliency against the A2/AD threats posed by the PRX. The New Glenn, with its smaller second stage landing booster and lower overall heat signature and rocket plume, has a slight survivability advantage over the Starship. The DM valued the C-17A marginally over the C-5M in survivability due to more tactically trained aircrews who operate regularly with Goddard's Joint Special Operations Command. The DM's judgments were highly consistent at 0.029.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	5	3	
C-17A	3	1	7	5	
Starship	1/5	1/7	1	1/3	
New Glenn	1/3	1/5	3	1	
Sum	4.533	1.676	16.000	9.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.221	0.199	0.313	0.321	0.263
C-17A	0.662	0.597	0.438	0.536	0.558
Starship	0.044	0.085	0.063	0.036	0.057
New Glenn	0.074	0.119	0.188	0.107	0.122
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.263	0.186	0.284	0.366	4.118
C-17A	0.790	0.558	0.398	0.609	CI
Starship	0.053	0.080	0.057	0.041	0.039
New Glenn	0.088	0.112	0.171	0.122	CR
					0.044

Figure 17: Alternative Future Indo-Pacific 2030 - OPM (Simplicity)

The DM found simplicity to be a necessary priority in this alternative future and ranked the C-17A clearly above the other alternatives. With potentially inflated requirements caused by varying equipment criticality at Oberth ASFB, the DM judges the C-17A and its aircrews to best overcome these obstacles. Late system requests with changing requirements are well-suited for C-17A special operations aircrews. Cargo above and beyond the 3-D concrete printer robotic arms and ground-based augmentation system antennas may carry additional joint inspection requirements or Air Transportability Test Loading Activity (ATTLA) certifications which will pose increases in spacelift platform sequence of events. The DM judges the New Glenn to be simpler than the Starship due to its smaller and more agile footprint. The DM's judgments were highly consistent at 0.044.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/5	3	4	
C-17A	5	1	7	8	
Starship	1/3	1/7	1	3	
New Glenn	1/4	1/8	1/3	1	
Sum	6.583	1.468	11.333	16.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.152	0.136	0.265	0.250	0.201
C-17A	0.759	0.681	0.618	0.500	0.640
Starship	0.051	0.097	0.088	0.188	0.106
New Glenn	0.038	0.085	0.029	0.063	0.054
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.201	0.128	0.318	0.215	4.197
C-17A	1.004	0.640	0.741	0.430	CI
Starship	0.067	0.091	0.106	0.161	0.066
New Glenn	0.050	0.080	0.035	0.054	CR
					0.074

Figure 18: Alternative Future Indo-Pacific 2030 - OPM (Flexibility)

The DM judged flexibility to be a desirable priority in this alternative future and ranked the C-17A above the C-5M and the two spacelift platforms. Oberth ASFB's single runway operation and degraded airfield with limited taxiway and apron options to egress and offload cargo give the advantage to the C-17A. An unanticipated change in the dynamic environment at Oberth could lead command and control to direct a landing elsewhere and the maximum aircraft on ground (MOG) issues with limited apron space could require the C-17A to engine-running offload its cargo near the runway and perform backing operations to egress the airfield. The DM's judgments were consistent at 0.074.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	5	6	
C-17A	1/3	1	3	4	
Starship	1/5	1/3	1	3	
New Glenn	1/6	1/4	1/3	1	
Sum	1.700	4.583	9.333	14.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.588	0.655	0.536	0.429	0.552
C-17A	0.196	0.218	0.321	0.286	0.255
Starship	0.118	0.073	0.107	0.214	0.128
New Glenn	0.098	0.055	0.036	0.071	0.065
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.552	0.766	0.640	0.390	4.150
C-17A	0.184	0.255	0.384	0.260	CI
Starship	0.110	0.085	0.128	0.195	0.050
New Glenn	0.092	0.064	0.043	0.065	CR
					0.056

Figure 19: Alternative Future Indo-Pacific 2030 - OPM (Attainability)

The DM did not find attainability to be a priority for this alternative future. Should follow-on events in theater require materiel and support capacity to commence operations at an acceptable level of risk, the DM judges the C-5M to be superior than the other alternatives in this alternative future. With the tyranny of distance in the Pacific and limited aerial refueling assets available for strategic airlift, the C-5Ms superior maximum takeoff gross weight, range, and outsized cargo compartment leads the DM to strongly favor it over the other alternatives. Similarly, the DM judged the Starship over the New Glenn due to its superior payload volume and useful mass to low earth orbit. The DM's judgments were consistent at 0.056.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	5	4	
C-17A	3	1	6	5	
Starship	1/5	1/6	1	1/3	
New Glenn	1/4	1/5	3	1	
Sum	4.450	1.700	15.000	10.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.225	0.196	0.333	0.387	0.285
C-17A	0.674	0.588	0.400	0.484	0.537
Starship	0.045	0.098	0.067	0.032	0.060
New Glenn	0.056	0.118	0.200	0.097	0.118
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.285	0.179	0.302	0.471	4.209
C-17A	0.856	0.537	0.363	0.588	CI
Starship	0.057	0.089	0.060	0.039	0.070
New Glenn	0.071	0.107	0.181	0.118	CR
					0.078

Figure 20: Alternative Future Indo-Pacific 2030 - OPM (Sustainability)

The DM did not judge sustainability to be a priority for this alternative future. Should the Joint Force require materiel and support capacity requirements delivered at an acceptable level of risk, the DM strongly favors the C-17A above the other alternatives. Long-term sustainability factors including location of sustainment operations, base operating support, and station interval all weighed favorably for the C-17A. The C-17A has a smaller footprint than the C-5M allowing it to operate at a wider variety of airfields, its aircrews require less station ground time as compared to the C-5M, and it has a superior mission capable rate over the C-5M. The DM's judgments were consistent at 0.078.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/4	4	5	
C-17A	4	1	5	7	
Starship	1/4	1/5	1	5	
New Glenn	1/5	1/7	1/5	1	
Sum	5.450	1.593	10.200	18.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.183	0.157	0.392	0.278	0.253
C-17A	0.734	0.628	0.490	0.389	0.560
Starship	0.046	0.126	0.098	0.278	0.137
New Glenn	0.037	0.090	0.020	0.056	0.050
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.253	0.140	0.547	0.252	4.407
C-17A	1.010	0.560	0.684	0.353	CI
Starship	0.063	0.112	0.137	0.252	0.136
New Glenn	0.051	0.080	0.027	0.050	CR
					0.152

Figure 21: Alternative Future Indo-Pacific 2030 - OPM (Economy)

The DM did not find economy to be a priority for this alternative future. Should the mission transition to one that is enduring, the Combatant Commander will require the correct amount of personnel and materiel to achieve success within acceptable levels of risk. The logistics principle of economy will eliminate redundancy by minimizing the cost per pound of payload thereby maximizing the MTM/D capacity of the fleet. The DM judged the C-17A to be superior in delivering economy in terms of MTM/D due to fleet size. If the C-17A fleet available for the mission is equivalent to the available C-5M fleet, then the C-5M would be superior in delivering economy. The DM's judgments were acceptable at 0.152.

3.7.2 Alternative Future Indo-Pacific 2035

Overall Preference Matrix							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	1	3	1/3	3	2	3	1/3
Simplicity	1/3	1	1/6	1/2	1/4	1/2	1/7
Flexibility	3	6	1	5	4	5	1/2
Economy	1/3	2	1/5	1	1/7	1/7	1/9
Attainability	1/2	4	1/4	7	1	2	1/5
Sustainability	1/3	2	1/5	7	1/2	1	1/5
Survivability	3	7	2	9	5	5	1
Sum	8.500	25.000	4.150	32.500	12.893	16.643	2.487
Normalization							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.118	0.120	0.080	0.092	0.155	0.180	0.134
Simplicity	0.039	0.040	0.040	0.015	0.019	0.030	0.057
Flexibility	0.353	0.240	0.241	0.154	0.310	0.300	0.201
Economy	0.039	0.080	0.048	0.031	0.011	0.009	0.045
Attainability	0.059	0.160	0.060	0.215	0.078	0.120	0.080
Sustainability	0.039	0.080	0.048	0.215	0.039	0.060	0.080
Survivability	0.353	0.280	0.482	0.277	0.388	0.300	0.402
							RVV (Crit)
							0.126
							0.035
							0.257
							0.038
							0.110
							0.080
							0.355
							1.000
Consistency							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.126	0.104	0.086	0.113	0.221	0.241	0.118
Simplicity	0.042	0.035	0.043	0.019	0.028	0.040	0.051
Flexibility	0.377	0.207	0.257	0.188	0.441	0.401	0.177
Economy	0.042	0.069	0.051	0.038	0.016	0.011	0.039
Attainability	0.063	0.138	0.064	0.263	0.110	0.161	0.071
Sustainability	0.042	0.069	0.051	0.263	0.055	0.080	0.071
Survivability	0.377	0.242	0.514	0.338	0.552	0.401	0.355
							λ max
							7.728
							CI
							0.121
							CR
							0.090

Figure 22: Alternative Future Indo-Pacific 2035 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: survivability, flexibility, responsiveness, attainability, and sustainability. Survivability is the most critical criterion due to the PRX's persistent A2/AD threats in the region. Flexibility is essential to execute the Quad's agile and anticipatory operational scheme of tactical maneuver to sustain its Joint Forces. Responsiveness is a necessary consideration to enable the Quad's survivability and flexibility. Attainability and sustainability are desirable due to the ongoing and projected stalemate between the Quad and the PRX leading to protracted conflict. The criteria of economy and simplicity are insignificant in this alternative future. The DM's judgments were consistent at 0.090.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	1/7	1/7	
C-17A	3	1	1/5	1/5	
Starship	7	5	1	1/3	
New Glenn	7	5	3	1	
Sum	18.000	11.333	4.343	1.676	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.056	0.029	0.033	0.085	0.051
C-17A	0.167	0.088	0.046	0.119	0.105
Starship	0.389	0.441	0.230	0.199	0.315
New Glenn	0.389	0.441	0.691	0.597	0.529
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.051	0.035	0.045	0.076	4.232
C-17A	0.152	0.105	0.063	0.106	CI
Starship	0.355	0.525	0.315	0.176	0.077
New Glenn	0.355	0.525	0.944	0.529	CR
					0.087

Figure 23: Alternative Future Indo-Pacific 2035 - OPM (Survivability)

The DM found survivability to be the most critical criterion in this alternative future and ranked the New Glenn as the top alternative above the Starship and the two strategic airlift platforms. The PRX's widespread A2/AD capabilities in the Indo-Pacific region pose extremely high levels of risk to strategic airlift platforms. As a result, the DM strongly favored the New Glenn and Starship over the C-17A and C-5M for their ability to largely maintain freedom of maneuver. The DM slightly favored the New Glenn over the Starship for its smaller overall signature, granting it a minor survivability advantage. The C-17 ranked marginally higher than the C-5M due to its more tactically trained aircrews. The DM's judgments were consistent at 0.087.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	1/3	1/4	
C-17A	1/3	1	1/5	1/6	
Starship	3	5	1	1	
New Glenn	4	6	1	1	
Sum	8.333	15.000	2.533	2.417	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.120	0.200	0.132	0.103	0.139
C-17A	0.040	0.067	0.079	0.069	0.064
Starship	0.360	0.333	0.395	0.414	0.375
New Glenn	0.480	0.400	0.395	0.414	0.422
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.139	0.191	0.125	0.106	4.060
C-17A	0.046	0.064	0.075	0.070	CI
Starship	0.416	0.318	0.375	0.422	0.020
New Glenn	0.555	0.382	0.375	0.422	CR
					0.022

Figure 24: Alternative Future Indo-Pacific 2035 - OPM (Flexibility)

The DM judged flexibility to be an essential priority in this alternative future and ranked New Glenn and Starship above the two strategic airlift alternatives. Strategic airlift is generally more flexible than strategic spacelift due to its ability to pivot with unanticipated changes in dynamic environments especially in the preparation phase prior to flight. The consistent logistics requirements of materiel across all Quad bases negate this advantage of flexibility for strategic airlift. Persistently dynamic basing constraints in the execution of ACE operations provides a significant advantage to strategic spacelift. The PTP replenishment capability provided by the Starship and New Glenn provide the principal advantage in this alternative future. The DM considers the C-5M to be slightly more flexible than the C-17A due to its increased range and resulting ability to be re-tasked to a different Quad base. The DM's judgments were highly consistent at 0.022.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	1/7	1/5	
C-17A	1/3	1	1/9	1/7	
Starship	7	9	1	4	
New Glenn	5	7	1/4	1	
Sum	13.333	20.000	1.504	5.343	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.075	0.150	0.095	0.037	0.089
C-17A	0.025	0.050	0.074	0.027	0.044
Starship	0.525	0.450	0.665	0.749	0.597
New Glenn	0.375	0.350	0.166	0.187	0.270
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.089	0.132	0.085	0.054	4.241
C-17A	0.030	0.044	0.066	0.039	CI
Starship	0.625	0.395	0.597	1.078	0.080
New Glenn	0.447	0.307	0.149	0.270	CR
					0.090

Figure 25: Alternative Future Indo-Pacific 2035 - OPM (Responsiveness)

The DM found responsiveness to be a necessary priority in this alternative future and ranked the Starship above all other alternatives including the New Glenn. While the New Glenn's velocity matches that of the Starship, the DM strongly favored the Starship for its 222% advantage in useful mass payload capability (Table 1). While the Starship has a 138% advantage in payload capacity over the C-5M, it has a significantly superior velocity advantage. Similarly, the DM slightly favored the C-5M over the C-17A due to its increased payload capacity. The consistency of materiel requirements across Quad bases negates the typical productivity (9) advantage that strategic airlift has in decreased origin to onload flying time. Adding to the responsiveness of the Starship and New Glenn is the lack of a requirement for crew rest in the mission's sequence of events. The DM's judgments were acceptable at 0.090.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	2	5	7	
C-17A	1/2	1	2	4	
Starship	1/5	1/2	1	3	
New Glenn	1/7	1/4	1/3	1	
Sum	1.843	3.750	8.333	15.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.543	0.533	0.600	0.467	0.536
C-17A	0.271	0.267	0.240	0.267	0.261
Starship	0.109	0.133	0.120	0.200	0.140
New Glenn	0.078	0.067	0.040	0.067	0.063
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.536	0.522	0.702	0.439	4.052
C-17A	0.268	0.261	0.281	0.251	CI
Starship	0.107	0.131	0.140	0.188	0.017
New Glenn	0.077	0.065	0.047	0.063	CR
					0.019

Figure 26: Alternative Future Indo-Pacific 2035 - OPM (Attainability)

The DM judged attainability to be a desirable priority in this alternative future and ranked the C-5M above the other alternatives. The protracted conflict across the expansive Indo-Pacific region eventually leads to the prioritization of the logistics principle of attainability. As the Quad nations increasingly mitigate the PRX threats in the region, the capacity of strategic airlift becomes increasingly significant. As responsiveness and capacity transition beyond the area of mission vulnerability (Figure 12), the C-5M coupled with the prevalent availability of autonomous aerial refueling capability from the Quad's MQ-175 fleet and the ability to tanker significant fuel stores can overcome the tyranny of distance. The strategic spacelift fleet is inferior in the attainability phase due to increased platform reconstitution timelines and the limited number of ASFBs in the region. The DM's judgments were highly consistent at 0.019.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/2	2	4	
C-17A	2	1	5	7	
Starship	1/2	1/5	1	1/3	
New Glenn	1/4	1/7	3	1	
Sum	3.750	1.843	11.000	12.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.267	0.271	0.182	0.324	0.261
C-17A	0.533	0.543	0.455	0.568	0.525
Starship	0.133	0.109	0.091	0.027	0.090
New Glenn	0.067	0.078	0.273	0.081	0.124
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.261	0.262	0.180	0.498	4.372
C-17A	0.522	0.525	0.450	0.871	CI
Starship	0.131	0.105	0.090	0.041	0.124
New Glenn	0.065	0.075	0.270	0.124	CR
					0.139

Figure 27: Alternative Future Indo-Pacific 2035 - OPM (Sustainability)

The DM found sustainability to also be a desirable priority in this alternative future and ranked the C-17A above the C-5M and the two spacelift platforms. The C-17A fleet size (Table 7) provides a significant advantage to the Combatant Commander in sustaining a high MTM/D capacity. Even with a payload capacity that is over 50% less than the C-5M over long distances, the C-17A's larger fleet size gives it a significant advantage in sustaining the supported force's long-term requirements (Table 6). Another key factor favoring the C-17A over the C-5M is base operating support for the C-17A from the Quad nations who also have the aircraft and maintenance support in their fleets. The strategic spacelift fleet can augment the logistics cycle in the sustainability phase but the Combatant Commander will use the platforms sparingly due to high costs. The DM's judgments were acceptable at 0.139.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/4	6	3	
C-17A	4	1	8	5	
Starship	1/6	1/8	1	1/4	
New Glenn	1/3	1/5	4	1	
Sum	5.500	1.575	19.000	9.250	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.182	0.159	0.316	0.324	0.245
C-17A	0.727	0.635	0.421	0.541	0.581
Starship	0.030	0.079	0.053	0.027	0.047
New Glenn	0.061	0.127	0.211	0.108	0.127
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.245	0.145	0.284	0.380	4.214
C-17A	0.981	0.581	0.379	0.633	CI
Starship	0.041	0.073	0.047	0.032	0.071
New Glenn	0.082	0.116	0.189	0.127	CR
					0.080

Figure 28: Alternative Future Indo-Pacific 2035 - OPM (Economy)

The DM did not judge economy to be a priority for this alternative future. Goddard's partners in the Quad have helped to minimize cost per pound of payload by providing expansive access to their Indo-Pacific located aerial ports, airports, and spaceports. This has served to greatly minimize the distance traveled by Goddard's Joint Force. The Quad expects the overall mission to eventually draw down with PRX's resource challenges and will not require an enduring force posture. The DM judges the C-17A to be superior in delivering economy in terms of FCD/D due to fleet size and found the New Glenn more economically feasible than the Starship to support the Quad's dispersed basing construct. The DM's judgments were consistent at 0.080.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	4	2	
C-17A	3	1	6	4	
Starship	1/4	1/6	1	1/3	
New Glenn	1/2	1/4	3	1	
Sum	4.750	1.750	14.000	7.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.211	0.190	0.286	0.273	0.240
C-17A	0.632	0.571	0.429	0.545	0.544
Starship	0.053	0.095	0.071	0.045	0.066
New Glenn	0.105	0.143	0.214	0.136	0.150
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.240	0.181	0.265	0.299	4.082
C-17A	0.720	0.544	0.397	0.599	CI
Starship	0.060	0.091	0.066	0.050	0.027
New Glenn	0.120	0.136	0.199	0.150	CR
					0.031

Figure 29: Alternative Future Indo-Pacific 2035 - OPM (Simplicity)

The DM did not find simplicity to be a priority for this alternative future. The Quad's superior command and control, honed in annual exercises in the Indo-Pacific region, has greatly reduced the friction of combat. The lack of importance placed on the logistics principle of economy contributes to the low priority on the principle of simplicity. Late system requests or inflated requirements are uncommon due to the consistent logistics requirements of the Quad's Joint Forces. The DM judges the C-17A above the other alternatives in this alternative future. The DM's judgments were highly consistent at 0.031.

3.7.3 Alternative Future Indo-Pacific 2040

Overall Preference Matrix							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	1	1/2	1	1/3	1/6	1/5	2
Simplicity	2	1	2	1	1/5	1/4	4
Flexibility	1	1/2	1	1/4	1/8	1/7	2
Economy	3	1	4	1	1/3	1/2	4
Attainability	6	5	8	3	1	1	8
Sustainability	5	4	7	2	1	1	8
Survivability	1/2	1/4	1/2	1/4	1/8	1/8	1
Sum	18.500	12.250	23.500	7.833	2.950	3.218	29.000
Normalization							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.054	0.041	0.043	0.043	0.056	0.062	0.069
Simplicity	0.108	0.082	0.085	0.128	0.068	0.078	0.138
Flexibility	0.054	0.041	0.043	0.032	0.042	0.044	0.069
Economy	0.162	0.082	0.170	0.128	0.113	0.155	0.138
Attainability	0.324	0.408	0.340	0.383	0.339	0.311	0.276
Sustainability	0.270	0.327	0.298	0.255	0.339	0.311	0.276
Survivability	0.027	0.020	0.021	0.032	0.042	0.039	0.034
							RVV (Crit)
							0.053
							0.098
							0.046
							0.135
							0.340
							0.297
							0.031
							1.000
Consistency							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.053	0.049	0.046	0.045	0.057	0.059	0.062
Simplicity	0.105	0.098	0.093	0.135	0.068	0.074	0.124
Flexibility	0.053	0.049	0.046	0.034	0.043	0.042	0.062
Economy	0.158	0.098	0.186	0.135	0.113	0.148	0.124
Attainability	0.315	0.490	0.372	0.406	0.340	0.297	0.247
Sustainability	0.263	0.392	0.325	0.271	0.340	0.297	0.247
Survivability	0.026	0.024	0.023	0.034	0.043	0.037	0.031
							λ max
							7.124
							CI
							0.021
							CR
							0.015

Figure 30: Alternative Future Indo-Pacific 2040 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: attainability, sustainability, economy, simplicity, and responsiveness. Attainability and sustainability are the most critical criteria due to Akiyama's immediate and long-term humanitarian supply needs. Economy is essential as a corollary to requiring sustainability. Simplicity is a necessary consideration to support non-stop sorties to Akiyama's affected prefectures. Responsiveness is desirable due to Akiyama requiring the movement of over 37,500 short tons of humanitarian supplies and life-saving equipment. The criteria of flexibility and survivability are insignificant in this alternative future. The DM's judgments were highly consistent at 0.015.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	2	3	
C-17A	3	1	3	4	
Starship	1/2	1/3	1	3	
New Glenn	1/3	1/4	1/3	1	
Sum	4.833	1.917	6.333	11.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.207	0.174	0.316	0.273	0.242
C-17A	0.621	0.522	0.474	0.364	0.495
Starship	0.103	0.174	0.158	0.273	0.177
New Glenn	0.069	0.130	0.053	0.091	0.086
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.242	0.165	0.354	0.257	4.145
C-17A	0.727	0.495	0.531	0.343	CI
Starship	0.121	0.165	0.177	0.257	0.048
New Glenn	0.081	0.124	0.059	0.086	CR
					0.054

Figure 31: Alternative Future Indo-Pacific 2040 - OPM (Attainability)

The DM found attainability to be a critical criterion in this alternative future and ranked the C-17A as the top alternative with the C-5M second. Akiyama's immediate requirement is the supply of food and water to its stranded citizens. The C-17A is uniquely suited, among the four alternatives, to airdrop these necessities. The ability to initiate operations without the inherent delays in the normal bed down process provides a clear advantage to the C-17A. The C-17A will require aerial refueling to accomplish airdrop in this alternative future. The FCD/D (11) metric favors the C-17A over the C-5M by an approximate factor of two even with an average payload disadvantage. The C-17A makes up for it with a fleet size almost quadruple the C-5M and an approximately 50% higher UTE rate. The DM's judgments were consistent at 0.054.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	2	5	5	
C-17A	1/2	1	4	4	
Starship	1/5	1/4	1	1/3	
New Glenn	1/5	1/4	3	1	
Sum	1.900	3.500	13.000	10.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.526	0.571	0.385	0.484	0.492
C-17A	0.263	0.286	0.308	0.387	0.311
Starship	0.105	0.071	0.077	0.032	0.071
New Glenn	0.105	0.071	0.231	0.097	0.126
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.492	0.622	0.357	0.630	4.189
C-17A	0.246	0.311	0.286	0.504	CI
Starship	0.098	0.078	0.071	0.042	0.063
New Glenn	0.098	0.078	0.214	0.126	CR
					0.071

Figure 32: Alternative Future Indo-Pacific 2040 - OPM (Sustainability)

The DM judged sustainability to also be a critical priority in this alternative future and ranked the C-5M slightly above the C-17A and clearly above the spacelift alternatives. With the severe loss of life and extreme damage to the prefectures closest to the Akiyama Trench, the operation requires a long-term delivery of 37,500 short tons of equipment and supplies. The C-5M can achieve closure (13) on 82.6M pounds of cargo with 10 aircraft in the span of 98 days while the C-17A would require 18 aircraft in approximately as many days. The C-17A is slightly hampered by the 1+45 ground refueling quick turn due to the distance to Akiyama. The New Glenn was slightly favored over the Starship due to more spaceports supporting the platform decreasing origin to onload delays. The DM's judgments were consistent at 0.071.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	4	6	
C-17A	1/3	1	3	4	
Starship	1/4	1/3	1	4	
New Glenn	1/6	1/4	1/4	1	
Sum	1.750	4.583	8.250	15.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.571	0.655	0.485	0.400	0.528
C-17A	0.190	0.218	0.364	0.267	0.260
Starship	0.143	0.073	0.121	0.267	0.151
New Glenn	0.095	0.055	0.030	0.067	0.062
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.528	0.779	0.603	0.370	4.216
C-17A	0.176	0.260	0.453	0.247	CI
Starship	0.132	0.087	0.151	0.247	0.072
New Glenn	0.088	0.065	0.038	0.062	CR
					0.081

Figure 33: Alternative Future Indo-Pacific 2040 - OPM (Economy)

The DM found economy to be an essential priority in this alternative future and ranked the C-5M above all other alternatives. Comparing a C-5M fleet of 10 aircraft versus a C-17A fleet of 18 aircraft with approximately equivalent closure timelines, the C-17A will cost Transportation Command \$48.8 million more for the entirety of the operation. This is due primarily to two factors: the C-17A can carry approximately half the payload of a C-5M requiring a larger fleet and the C-17A requiring a ground refueling quick turn adding to total costs. In this alternative future, spacelift has the potential to greatly reduce cost per pound of payload with the activation of the CRSF but is still significantly more costly than airlift. The DM's judgments were consistent at 0.081.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	4	7	
C-17A	1/3	1	2	6	
Starship	1/4	1/2	1	3	
New Glenn	1/7	1/6	1/3	1	
Sum	1.726	4.667	7.333	17.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.579	0.643	0.545	0.412	0.545
C-17A	0.193	0.214	0.273	0.353	0.258
Starship	0.145	0.107	0.136	0.176	0.141
New Glenn	0.083	0.036	0.045	0.059	0.056
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.545	0.775	0.565	0.390	4.086
C-17A	0.182	0.258	0.282	0.334	CI
Starship	0.136	0.129	0.141	0.167	0.029
New Glenn	0.078	0.043	0.047	0.056	CR
					0.032

Figure 34: Alternative Future Indo-Pacific 2040 - OPM (Simplicity)

The DM judged simplicity to be a necessary priority in this alternative future and ranked the C-5M above the other alternatives. The ability of the C-5M to fly direct from the west coast of Goddard to Akiyama gives it a simplicity advantage over the C-17A. The C-5M can accommodate all of the necessary cargo in the operation to include the outsized housing trailers, helicopters, and cranes. The Starship is slightly favored over the New Glenn for its larger payload fairing able to accommodate a wider variety of cargo. The DM's judgments were highly consistent at 0.032.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	4	1/6	1/4	
C-17A	1/4	1	1/8	1/6	
Starship	6	8	1	4	
New Glenn	4	6	1/4	1	
Sum	11.250	19.000	1.542	5.417	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.089	0.211	0.108	0.046	0.113
C-17A	0.022	0.053	0.081	0.031	0.047
Starship	0.533	0.421	0.649	0.738	0.585
New Glenn	0.356	0.316	0.162	0.185	0.255
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.113	0.187	0.098	0.064	4.287
C-17A	0.028	0.047	0.073	0.042	CI
Starship	0.681	0.373	0.585	1.018	0.096
New Glenn	0.454	0.280	0.146	0.255	CR
					0.108

Figure 35: Alternative Future Indo-Pacific 2040 - OPM (Responsiveness)

The DM found responsiveness to also be a desirable priority in this alternative future and ranked the Starship above the New Glenn and the airlift alternatives. The activation of the CRSF by Goddard's Secretary of Defense enables access to the growing network of spacelift platforms. In terms of responsiveness, the Starship is strongly favored over the New Glenn primarily for its ability to carry more payload in an equivalent timeline. Likewise, the C-5M is favored over the C-17 due to its ability to fly direct to Akiyama and its evident capacity advantage. It is noteworthy that the spacelift platforms are severely limited in their ability to carry rolling stock. The DM's judgments were acceptable at 0.108.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	2	3	
C-17A	1	1	2	3	
Starship	1/2	1/2	1	2	
New Glenn	1/3	1/3	1/2	1	
Sum	2.833	2.833	5.500	9.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.353	0.353	0.364	0.333	0.351
C-17A	0.353	0.353	0.364	0.333	0.351
Starship	0.176	0.176	0.182	0.222	0.189
New Glenn	0.118	0.118	0.091	0.111	0.109
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.351	0.351	0.378	0.328	4.010
C-17A	0.351	0.351	0.378	0.328	CI
Starship	0.175	0.175	0.189	0.219	0.003
New Glenn	0.117	0.117	0.095	0.109	CR
					0.004

Figure 36: Alternative Future Indo-Pacific 2040 - OPM (Flexibility)

The DM did not judge flexibility to be a priority for this alternative future. While novel loadmaster designs for spacelift platforms have been realized increasing the variety of cargo passing joint inspection requirements, the ability to pivot cargo types during normal sequence of events is still more time consuming than with airlift platforms. The C-5Ms unrefueled range with substantial payload and the C-17As airdrop capability are noteworthy in achieving flexibility. The DM gives the Starship a slight advantage over the New Glenn due to its substantial payload capacity allowing a wider array of cargo to be carried. The DM's judgments were highly consistent at 0.004.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1	1	
C-17A	1	1	1	1	
Starship	1	1	1	1	
New Glenn	1	1	1	1	
Sum	4.000	4.000	4.000	4.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.250	0.250	0.250	0.250	0.250
C-17A	0.250	0.250	0.250	0.250	0.250
Starship	0.250	0.250	0.250	0.250	0.250
New Glenn	0.250	0.250	0.250	0.250	0.250
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.250	0.250	0.250	0.250	4.000
C-17A	0.250	0.250	0.250	0.250	CI
Starship	0.250	0.250	0.250	0.250	0.000
New Glenn	0.250	0.250	0.250	0.250	CR
					0.000

Figure 37: Alternative Future Indo-Pacific 2040 - OPM (Survivability)

The DM did not find survivability to be a priority for this alternative future. Each alternative was ranked equally survivable in this peacetime operation. The DM's judgments were perfectly consistent.

3.7.4 Alternative Future Europe 2030

Overall Preference Matrix							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	1	7	3	8	2	3	6
Simplicity	1/7	1	1/4	2	1/6	1/5	1/2
Flexibility	1/3	4	1	4	1/4	1/3	3
Economy	1/8	1/2	1/4	1	1/8	1/7	1/4
Attainability	1/2	6	4	8	1	1/2	4
Sustainability	1/3	5	3	7	2	1	1/3
Survivability	1/6	2	1/3	4	1/4	3	1
Sum	2.601	25.500	11.833	34.000	5.792	8.176	15.083
Normalization							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.384	0.275	0.254	0.235	0.345	0.367	0.398
Simplicity	0.055	0.039	0.021	0.059	0.029	0.024	0.033
Flexibility	0.128	0.157	0.085	0.118	0.043	0.041	0.199
Economy	0.048	0.020	0.021	0.029	0.022	0.017	0.017
Attainability	0.192	0.235	0.338	0.235	0.173	0.061	0.265
Sustainability	0.128	0.196	0.254	0.206	0.345	0.122	0.022
Survivability	0.064	0.078	0.028	0.118	0.043	0.367	0.066
							RVV (Crit)
							1.000
Consistency							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.323	0.260	0.330	0.199	0.429	0.546	0.655
Simplicity	0.046	0.037	0.027	0.050	0.036	0.036	0.055
Flexibility	0.108	0.149	0.110	0.099	0.054	0.061	0.328
Economy	0.040	0.019	0.027	0.025	0.027	0.026	0.027
Attainability	0.161	0.223	0.440	0.199	0.214	0.091	0.437
Sustainability	0.108	0.186	0.330	0.174	0.429	0.182	0.036
Survivability	0.054	0.074	0.037	0.099	0.054	0.546	0.109
							λ max
							8.179
							CI
							0.197
							CR
							0.146

Figure 38: Alternative Future Europe 2030 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: responsiveness, attainability, sustainability, flexibility, and survivability. Responsiveness is the most critical criterion due to the imminent threat to NAMA's eastern flank. Attainability is an essential criterion since NAMA's Response Force requires the initial capacity to initiate operations against Korolev at an acceptable level of risk. Sustainability is a necessary criterion in order to achieve efficient TPFDD closure for Operation Plan LAIKA. Flexibility and survivability are desirable criteria due to Korolev's ongoing A2/AD threats in theater. The criteria of simplicity and economy are insignificant in this alternative future. The DM's judgments were consistent at 0.146.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/2	4	6	
C-17A	2	1	3	5	
Starship	1/4	1/3	1	4	
New Glenn	1/6	1/5	1/4	1	
Sum	3.417	2.033	8.250	16.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.293	0.246	0.485	0.375	0.350
C-17A	0.585	0.492	0.364	0.313	0.438
Starship	0.073	0.164	0.121	0.250	0.152
New Glenn	0.049	0.098	0.030	0.063	0.060
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.350	0.219	0.608	0.360	4.224
C-17A	0.699	0.438	0.456	0.300	CI
Starship	0.087	0.146	0.152	0.240	0.075
New Glenn	0.058	0.088	0.038	0.060	CR
					0.084

Figure 39: Alternative Future Europe 2030 - OPM (Responsiveness)

The DM found responsiveness to be a critical criterion in this alternative future and ranked the C-17A as the top alternative. Korolev's precipitous invasion of Kadenyuk and Yurchikhin have threatened the security of NAMA's eastern flank necessitating a rapid response from Goddard. Operation Plan LAIKA calls for the reinforcement of NAMA's Response Force as well as existing bases in Europe. The C-17A is uniquely suited to move Goddard's Immediate Response Force via airdrop if necessary. The DM only slightly favors the C-17A over the C-5M due to the C-5M having the payload capacity and range to move Army Combat Aviation Brigades closest to NAMA's eastern flank. The DM strongly favored the Starship over the New Glenn for its significant capacity advantage. The DM's judgments were consistent at 0.084.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	3	5	
C-17A	1	1	5	6	
Starship	1/3	1/5	1	5	
New Glenn	1/5	1/6	1/5	1	
Sum	2.533	2.367	9.200	17.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.395	0.423	0.326	0.294	0.359
C-17A	0.395	0.423	0.543	0.353	0.428
Starship	0.132	0.085	0.109	0.294	0.155
New Glenn	0.079	0.070	0.022	0.059	0.057
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.359	0.428	0.464	0.287	4.237
C-17A	0.359	0.428	0.774	0.345	CI
Starship	0.120	0.086	0.155	0.287	0.079
New Glenn	0.072	0.071	0.031	0.057	CR
					0.089

Figure 40: Alternative Future Europe 2030 - OPM (Attainability)

The DM judged attainability to be an essential priority in this alternative future and ranked the C-17A slightly above the C-5M and well above the spacelift alternatives. Goddard, and NAMA by extension, cannot initiate operations at an acceptable level of risk without the FCD/D capability of the C-17A. The number of C-17A aircraft at Goddard's disposal combined with its surge UTE rate are unmatched. However, the DM places equal importance on the C-5M due to its unique capability to move heavy, outsized cargo such as the DABS closer to Korolev's threatening positions. To help achieve the Joint Force's initial materiel and support capacity, a dozen Starship's and New Glenn's are available on alert posture; these are helpful during the initial stages of the Goddard's logistics operation. The Starship is strongly favored over the New Glenn for its significant capacity advantage. The DM's judgments were consistent at 0.089.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/2	3	6	
C-17A	2	1	5	7	
Starship	1/3	1/5	1	3	
New Glenn	1/6	1/7	1/3	1	
Sum	3.500	1.843	9.333	17.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.286	0.271	0.321	0.353	0.308
C-17A	0.571	0.543	0.536	0.412	0.515
Starship	0.095	0.109	0.107	0.176	0.122
New Glenn	0.048	0.078	0.036	0.059	0.055
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.308	0.258	0.366	0.330	4.068
C-17A	0.616	0.515	0.609	0.384	CI
Starship	0.103	0.103	0.122	0.165	0.023
New Glenn	0.051	0.074	0.041	0.055	CR
					0.025

Figure 41: Alternative Future Europe 2030 - OPM (Sustainability)

The DM found sustainability to be a necessary priority in this alternative future and ranked the C-17A above all other alternatives. With materiel and support capacity requirements transitioning to the necessary level to achieve long-term objectives, the metric of responsiveness is not as much of an issue as closure. A fleet size quadruple that of the C-5M with similar velocity and payload, the C-17A has an advantage in a decreased closure timeline especially with no ground refuel necessary as there was in the Indo-Pacific alternative futures. The C-5M continues to move Army Combat Aviation Brigades while the activated CRAF carries 42 pallet position equivalents on its 747-8F platforms. With the CRSF still unavailable, Goddard cannot effectively leverage its commercial space industry in the sustainability phase of the operation. The DM's judgments were highly consistent at 0.025.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/4	1/3	1/3	
C-17A	4	1	3	5	
Starship	3	1/3	1	2	
New Glenn	3	1/5	1/2	1	
Sum	11.000	1.783	4.833	8.333	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.091	0.140	0.069	0.040	0.085
C-17A	0.364	0.561	0.621	0.600	0.536
Starship	0.273	0.187	0.207	0.240	0.227
New Glenn	0.273	0.112	0.103	0.120	0.152
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.085	0.134	0.076	0.051	4.191
C-17A	0.340	0.536	0.680	0.760	CI
Starship	0.255	0.179	0.227	0.304	0.064
New Glenn	0.255	0.107	0.113	0.152	CR
					0.072

Figure 42: Alternative Future Europe 2030 - OPM (Flexibility)

The DM judged flexibility to be a desirable priority in this alternative future and ranked the C-17A above the other alternatives. The ability to pivot logistics to highly evolving operational requirements in Kadenyuk, Yurchikhin, and the Baltic states will contribute significantly to Goddard's success in Operation Plan LAIKA. Without an activated CRSF and the CRAF relegated to low-risk logistics movements, the DM judged the C-17A as the preferred platform to rapidly aggregate, disaggregate, and re-aggregate the NAMA Response Force across Europe. It has the unique capability across all alternatives to airdrop cargo as well as land on austere airfields. Its special operations crews are well trained in the A2/AD environment as well as operational aerial refueling to extend range when necessary. The spacelift alternatives outranked the C-5M due to their lower landing zone requirements. The DM's judgments were consistent at 0.072.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/2	1/3	1/3	
C-17A	2	1	1/2	1/2	
Starship	3	2	1	1	
New Glenn	3	2	1	1	
Sum	9.000	5.500	2.833	2.833	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.111	0.091	0.118	0.118	0.109
C-17A	0.222	0.182	0.176	0.176	0.189
Starship	0.333	0.364	0.353	0.353	0.351
New Glenn	0.333	0.364	0.353	0.353	0.351
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.109	0.095	0.117	0.117	4.010
C-17A	0.219	0.189	0.175	0.175	CI
Starship	0.328	0.378	0.351	0.351	0.003
New Glenn	0.328	0.378	0.351	0.351	CR
					0.004

Figure 43: Alternative Future Europe 2030 - OPM (Survivability)

The DM found survivability to also be a desirable priority in this alternative future and ranked the Starship and the New Glenn above the airlift alternatives. Five years of debilitating sanctions have crippled the sustainment of Korolev's military, especially in its integrated air defense and command and control divisions. Because of this, Korolev has focused its priority on eliminating air to air threats while they are on the ground. The C-17A, C-5M, and their aircrews are uniquely vulnerable during their quick turn operations at forward aerial ports. While the Starship and New Glenn are equally vulnerable on the ground, they are uncrewed platforms that have the ability to autonomously offload cargo. The DM's judgments were highly consistent at 0.004.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	2	5	
C-17A	3	1	4	7	
Starship	1/2	1/4	1	3	
New Glenn	1/5	1/7	1/3	1	
Sum	4.700	1.726	7.333	16.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.213	0.193	0.273	0.313	0.248
C-17A	0.638	0.579	0.545	0.438	0.550
Starship	0.106	0.145	0.136	0.188	0.144
New Glenn	0.043	0.083	0.045	0.063	0.058
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.248	0.183	0.288	0.292	4.068
C-17A	0.743	0.550	0.575	0.408	CI
Starship	0.124	0.138	0.144	0.175	0.023
New Glenn	0.050	0.079	0.048	0.058	CR
					0.025

Figure 44: Alternative Future Europe 2030 - OPM (Simplicity)

The DM did not judge simplicity to be a priority for this alternative future. The DM's judgments were highly consistent at 0.025.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/4	6	3	
C-17A	4	1	8	5	
Starship	1/6	1/8	1	1/5	
New Glenn	1/3	1/5	5	1	
Sum	5.500	1.575	20.000	9.200	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.182	0.159	0.300	0.326	0.242
C-17A	0.727	0.635	0.400	0.543	0.576
Starship	0.030	0.079	0.050	0.022	0.045
New Glenn	0.061	0.127	0.250	0.109	0.137
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.242	0.144	0.272	0.410	4.271
C-17A	0.967	0.576	0.363	0.683	CI
Starship	0.040	0.072	0.045	0.027	0.090
New Glenn	0.081	0.115	0.227	0.137	CR
					0.101

Figure 45: Alternative Future Europe 2030 - OPM (Economy)

The DM did not find economy to be a priority for this alternative future. The DM's judgments were acceptable at 0.101.

3.7.5 Alternative Future Europe 2035

Overall Preference Matrix							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	1	1/2	7	6	2	3	5
Simplicity	2	1	8	7	3	4	6
Flexibility	1/7	1/8	1	1/2	1/5	1/4	1/3
Economy	1/6	1/7	2	1	1/4	1/4	1
Attainability	1/2	1/3	5	4	1	2	3
Sustainability	1/3	1/4	4	4	1/2	1	2
Survivability	1/5	1/6	3	1	1/3	1/2	1
Sum	4.343	2.518	30.000	23.500	7.283	11.000	18.333
Normalization							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.230	0.199	0.233	0.255	0.275	0.273	0.273
Simplicity	0.461	0.397	0.267	0.298	0.412	0.364	0.327
Flexibility	0.033	0.050	0.033	0.021	0.027	0.023	0.018
Economy	0.038	0.057	0.067	0.043	0.034	0.023	0.055
Attainability	0.115	0.132	0.167	0.170	0.137	0.182	0.164
Sustainability	0.077	0.099	0.133	0.170	0.069	0.091	0.109
Survivability	0.046	0.066	0.100	0.043	0.046	0.045	0.055
							RVV (Crit)
							0.248
							0.361
							0.029
							0.045
							0.152
							0.107
							0.057
							1.000
Consistency							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.248	0.180	0.206	0.271	0.305	0.321	0.286
Simplicity	0.496	0.361	0.235	0.316	0.457	0.428	0.343
Flexibility	0.035	0.045	0.029	0.023	0.030	0.027	0.019
Economy	0.041	0.052	0.059	0.045	0.038	0.027	0.057
Attainability	0.124	0.120	0.147	0.181	0.152	0.214	0.172
Sustainability	0.083	0.090	0.117	0.181	0.076	0.107	0.114
Survivability	0.050	0.060	0.088	0.045	0.051	0.053	0.057
							λ max
							7.191
							CI
							0.032
							CR
							0.024

Figure 46: Alternative Future Europe 2035 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: simplicity, responsiveness, attainability, and sustainability. Simplicity is the most critical criterion due to the significant command and control synchronization, in-transit visibility, and unity of effort required to resupply NAMA allies. Responsiveness is essential to circumvent the geographic limitations imposed by the Arctic region. Attainability is a necessary consideration to meet the immediate logistics requirements of Nyberg and other NAMA allies. Sustainability is desirable due to the long-term requirements of supporting FONOPS in the Northern Sea Route. The criteria of survivability, economy, and flexibility are insignificant in this alternative future. The DM's judgments were highly consistent at 0.024.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	1/5	1/4	
C-17A	3	1	1/4	1/3	
Starship	5	4	1	1	
New Glenn	4	3	1	1	
Sum	13.000	8.333	2.450	2.583	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.077	0.040	0.082	0.097	0.074
C-17A	0.231	0.120	0.102	0.129	0.145
Starship	0.385	0.480	0.408	0.387	0.415
New Glenn	0.308	0.360	0.408	0.387	0.366
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.074	0.048	0.083	0.091	4.100
C-17A	0.221	0.145	0.104	0.122	CI
Starship	0.369	0.582	0.415	0.366	0.033
New Glenn	0.295	0.436	0.415	0.366	CR
					0.038

Figure 47: Alternative Future Europe 2035 - OPM (Simplicity)

The DM found simplicity to be the most critical criterion in this alternative future and ranked the Starship slightly above the New Glenn. An overwhelming majority of bases supporting the freedom of international trade in the Northern Sea Route are in NAMA archipelagos. With tensions in the Arctic stabilizing following Korolev's shoot down of Goddard's RQ-920, the ability to be efficient in multinational planning with NAMA countries takes priority over responsiveness. Attaining unity of effort and synchronized command and control is made simpler with the ability to directly resupply forward Arctic bases; additional benefits include constant custody and in-transit visibility of cargo as well as fewer diplomatic clearance requirements with fewer enroute stops. The Starship outranks the New Glenn in simplicity due to the increased ability to pivot with heavier payloads. The DM's judgments were highly consistent at 0.038.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1/3	1/5	
C-17A	1	1	1/5	1/7	
Starship	3	5	1	1/5	
New Glenn	5	7	5	1	
Sum	10.000	14.000	6.533	1.543	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.100	0.071	0.051	0.130	0.088
C-17A	0.100	0.071	0.031	0.093	0.074
Starship	0.300	0.357	0.153	0.130	0.235
New Glenn	0.500	0.500	0.765	0.648	0.603
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.088	0.074	0.078	0.121	4.209
C-17A	0.088	0.074	0.047	0.086	CI
Starship	0.264	0.368	0.235	0.121	0.070
New Glenn	0.440	0.516	1.175	0.603	CR
					0.078

Figure 48: Alternative Future Europe 2035 - OPM (Responsiveness)

The DM judged responsiveness to be an essential priority in this alternative future and ranked the New Glenn clearly above all the other alternatives. Spacelift's unique capability to move cargo PTP from NAMA spaceports directly to the Arctic gives it a clear velocity advantage over airlift. The PTP capability negates the requirement for any enroute refueling stops, crew changes, or transloading to smaller and more tactical airlift platforms. The New Glenn was strongly favored over the Starship for its ability to land at a greater number of locations to include on the Navy's Next Generation Fast Combat Support Ships. The C-5M was slightly favored over the C-17A for its increased range but this was tempered with the C-17A's ability to land on one of Nyberg's ice runways using their Deep Freeze crews; the C-5M has the capability but has no trained crews. The DM's judgments were consistent at 0.078.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	1/5	1/4	
C-17A	3	1	1/4	1/3	
Starship	5	4	1	3	
New Glenn	4	3	1/3	1	
Sum	13.000	8.333	1.783	4.583	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.077	0.040	0.112	0.055	0.071
C-17A	0.231	0.120	0.140	0.073	0.141
Starship	0.385	0.480	0.561	0.655	0.520
New Glenn	0.308	0.360	0.187	0.218	0.268
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.071	0.047	0.104	0.067	4.184
C-17A	0.213	0.141	0.130	0.089	CI
Starship	0.355	0.564	0.520	0.805	0.061
New Glenn	0.284	0.423	0.173	0.268	CR
					0.069

Figure 49: Alternative Future Europe 2035 - OPM (Attainability)

The DM found attainability to be a necessary priority in this alternative future and ranked the Starship clearly above all other alternatives. The C-17A was slightly favored over the C-5M due to its greater platform reliability, especially in cold weather conditions. The C-17A's ability to airdrop as well as land on one of Nyberg's ice runways also allows it to deliver materiel and support capacity closer to the point of need. The FCD/D metric (11) is not a player in this alternative future since the same amount of C-17As and C-5Ms are available to Arctic Command. Spacelift maintains a clear advantage in attainability due mostly to its velocity advantage but partially to the New Glenn's ability to land on Fast Combat Support Ships in the Arctic. The DM's judgments were consistent at 0.069.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	3	1/3	1/2	
C-17A	1/3	1	1/6	1/4	
Starship	3	6	1	1	
New Glenn	2	4	1	1	
Sum	6.333	14.000	2.500	2.750	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.158	0.214	0.133	0.182	0.172
C-17A	0.053	0.071	0.067	0.091	0.070
Starship	0.474	0.429	0.400	0.364	0.416
New Glenn	0.316	0.286	0.400	0.364	0.341
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.172	0.211	0.139	0.171	4.041
C-17A	0.057	0.070	0.069	0.085	CI
Starship	0.515	0.422	0.416	0.341	0.014
New Glenn	0.344	0.282	0.416	0.341	CR
					0.015

Figure 50: Alternative Future Europe 2035 - OPM (Sustainability)

The DM judged sustainability to be a desirable priority in this alternative future and ranked the Starship slightly above the New Glenn and clearly above the other alternatives. With respect to number of missions required (12), the Starship and C-5M have average payload advantages over the New Glenn and C-17A. With regard to closure (13) timelines, spacelift has a clear advantage due to its far shorter round trip flying time; its onload times have improved to match airlift's combined round trip flying time and crew rest timelines. The Starship has a very slight advantage over the New Glenn in average payload that is mostly negated by New Glenn's greater fleet size. Adding to the sustainability equation is airlift's prevalent requirement for enroute refueling stops and transloading to LC-130 aircraft. The DM's judgments were highly consistent at 0.015.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1	1	
C-17A	1	1	1	1	
Starship	1	1	1	1	
New Glenn	1	1	1	1	
Sum	4.000	4.000	4.000	4.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.250	0.250	0.250	0.250	0.250
C-17A	0.250	0.250	0.250	0.250	0.250
Starship	0.250	0.250	0.250	0.250	0.250
New Glenn	0.250	0.250	0.250	0.250	0.250
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.250	0.250	0.250	0.250	4.000
C-17A	0.250	0.250	0.250	0.250	CI
Starship	0.250	0.250	0.250	0.250	0.000
New Glenn	0.250	0.250	0.250	0.250	CR
					0.000

Figure 51: Alternative Future Europe 2035 - OPM (Survivability)

The DM did not find survivability to be a priority in this alternative future and ranked all platforms equally. Korolev and PRX are no longer overtly threatening NAMA assets. The platforms themselves are statistically equally survivable. The DM's judgments were perfectly consistent.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	4	3	
C-17A	3	1	3	2	
Starship	1/4	1/3	1	1	
New Glenn	1/3	1/2	1	1	
Sum	4.583	2.167	9.000	7.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.218	0.154	0.444	0.429	0.311
C-17A	0.655	0.462	0.333	0.286	0.434
Starship	0.055	0.154	0.111	0.143	0.116
New Glenn	0.073	0.231	0.111	0.143	0.139
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.311	0.145	0.462	0.418	4.287
C-17A	0.934	0.434	0.347	0.279	CI
Starship	0.078	0.145	0.116	0.139	0.096
New Glenn	0.104	0.217	0.116	0.139	CR
					0.107

Figure 52: Alternative Future Europe 2035 - OPM (Economy)

The DM did not judge economy to be a priority for this alternative future. The CRSF has not been activated by Goddard's Secretary of Defense therefore airlift has a clear advantage in economy. The C-17A is slightly favored over the C-5M for its lower SAAM costs. The DM's judgments were acceptable at 0.107.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	2	2	2	
C-17A	1/2	1	2	2	
Starship	1/2	1/2	1	1	
New Glenn	1/2	1/2	1	1	
Sum	2.500	4.000	6.000	6.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.400	0.500	0.333	0.333	0.392
C-17A	0.200	0.250	0.333	0.333	0.279
Starship	0.200	0.125	0.167	0.167	0.165
New Glenn	0.200	0.125	0.167	0.167	0.165
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.392	0.558	0.329	0.329	4.061
C-17A	0.196	0.279	0.329	0.329	CI
Starship	0.196	0.140	0.165	0.165	0.020
New Glenn	0.196	0.140	0.165	0.165	CR
					0.023

Figure 53: Alternative Future Europe 2035 - OPM (Flexibility)

The DM did not find flexibility to be a priority for this alternative future. While the New Glenn has the capability to land on Fast Combat Support Ships in the Arctic, it is not technically feasible to redirect a rocket to an alternate landing zone once it has been launched. On the contrary, an airlift platform can be redirected to an alternate landing zone during a majority of its flight time; aircraft often divert to an alternate airport at the last minute of fuel reserves. This difference in alternate landing zone capabilities only provides airlift a very slight advantage in this alternative future since most landing zones in the Arctic must be committed to earlier than normal. The DM's judgments were highly consistent at 0.023.

3.7.6 Alternative Future Europe 2040

Overall Preference Matrix							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	1	2	5	7	7	7	1/7
Simplicity	1/2	1	2	5	5	5	1/9
Flexibility	1/5	1/2	1	4	4	4	1/9
Economy	1/7	1/5	1/4	1	1	1	1/9
Attainability	1/7	1/5	1/4	1	1	1	1/9
Sustainability	1/7	1/5	1/4	1	1	1	1/9
Survivability	7	9	9	9	9	9	1
Sum	9.129	13.100	17.750	28.000	28.000	28.000	1.698
Normalization							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.110	0.153	0.282	0.250	0.250	0.250	0.084
Simplicity	0.055	0.076	0.113	0.179	0.179	0.179	0.065
Flexibility	0.022	0.038	0.056	0.143	0.143	0.143	0.065
Economy	0.016	0.015	0.014	0.036	0.036	0.036	0.065
Attainability	0.016	0.015	0.014	0.036	0.036	0.036	0.065
Sustainability	0.016	0.015	0.014	0.036	0.036	0.036	0.065
Survivability	0.767	0.687	0.507	0.321	0.321	0.321	0.589
							RVV (Crit)
							0.197
							0.121
							0.087
							0.031
							0.031
							0.502
							1.000
Consistency							
	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
Responsiveness	0.197	0.241	0.436	0.218	0.218	0.218	0.072
Simplicity	0.098	0.121	0.174	0.155	0.155	0.155	0.056
Flexibility	0.039	0.060	0.087	0.124	0.124	0.124	0.056
Economy	0.028	0.024	0.022	0.031	0.031	0.031	0.056
Attainability	0.028	0.024	0.022	0.031	0.031	0.031	0.056
Sustainability	0.028	0.024	0.022	0.031	0.031	0.031	0.056
Survivability	1.378	1.086	0.785	0.280	0.280	0.280	0.502
							λ max
							7.635
							CI
							0.106
							CR
							0.078

Figure 54: Alternative Future Europe 2040 - OPM (Main Criteria)

Considering the top-level strategic guidance and the alternative future, the DM rank ordered the significant criteria as follows: survivability, responsiveness, simplicity, and flexibility. Survivability is the most critical criterion due to the requirement to insert a Quick Reaction Force into the diplomatic compound at Tereshkova. Responsiveness is essential with the threat to the compound assessed to increase substantially within six hours. Simplicity is a necessary consideration to ensure smooth command and control integration with constant custody and in-transit visibility of the Quick Reaction Force. Flexibility is desirable due to the ingress location potentially changing at the last minute between the diplomatic compound and the annex. The criteria of attainability, sustainability, and economy are insignificant in this alternative future. The DM's judgments were consistent at 0.078.

Survivability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1/3	1/3	
C-17A	1	1	1/3	1/3	
Starship	3	3	1	1	
New Glenn	3	3	1	1	
Sum	8.000	8.000	2.667	2.667	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.125	0.125	0.125	0.125	0.125
C-17A	0.125	0.125	0.125	0.125	0.125
Starship	0.375	0.375	0.375	0.375	0.375
New Glenn	0.375	0.375	0.375	0.375	0.375
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.125	0.125	0.125	0.125	4.000
C-17A	0.125	0.125	0.125	0.125	CI
Starship	0.375	0.375	0.375	0.375	0.000
New Glenn	0.375	0.375	0.375	0.375	CR
					0.000

Figure 55: Alternative Future Europe 2040 - OPM (Survivability)

The DM found survivability to be the most critical criterion in this alternative future and ranked both spacelift alternatives equally above the airlift alternatives. In fifteen years of spacelift launches by Goddard Transportation Command's commercial launch partners, there have been zero losses. Spacelift's greater velocity provides it an advantage in reducing the Leonov militant group's reaction time in utilizing their aging rocket propelled grenade capability. Adding to spacelift's advantage is its PTP capability while airlift will cause the Quick Reaction Force to travel from the closest airport to the diplomatic compound via armored vehicle convoy. Airdrop via C-17A is a distinct course of action but the inherent dangers associated with that type of insertion negates the overall capability advantage. The DM's judgments were perfectly consistent.

Responsiveness					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	1/7	1/6	
C-17A	3	1	1/5	1/4	
Starship	7	5	1	2	
New Glenn	6	4	1/2	1	
Sum	17.000	10.333	1.843	3.417	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.059	0.032	0.078	0.049	0.054
C-17A	0.176	0.097	0.109	0.073	0.114
Starship	0.412	0.484	0.543	0.585	0.506
New Glenn	0.353	0.387	0.271	0.293	0.326
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.054	0.038	0.072	0.054	4.101
C-17A	0.163	0.114	0.101	0.082	CI
Starship	0.380	0.569	0.506	0.652	0.034
New Glenn	0.326	0.455	0.253	0.326	CR
					0.038

Figure 56: Alternative Future Europe 2040 - OPM (Responsiveness)

The DM judged responsiveness to be an essential priority in this alternative future and ranked Starship above the New Glenn and the airlift alternatives. With the Goddard diplomatic compound in Tereshkova under greater attack within a six-hour window, the DM clearly preferred spacelift alternatives for their unmatched capability to move the Quick Reaction Force PTP from continental Goddard to Tereshkova in under an hour. While unprepared landing zones are not ideal for rocket recovery, the available soccer field within approximately a half mile is sufficient. The Starship was slightly favored over the New Glenn for its capacity advantage, allowing a larger Quick Reaction Force and associated weapons to be transported. The DM's judgments were highly consistent at 0.038.

Simplicity					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1/5	1/5	
C-17A	1	1	1/5	1/5	
Starship	5	5	1	1	
New Glenn	5	5	1	1	
Sum	12.000	12.000	2.400	2.400	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.083	0.083	0.083	0.083	0.083
C-17A	0.083	0.083	0.083	0.083	0.083
Starship	0.417	0.417	0.417	0.417	0.417
New Glenn	0.417	0.417	0.417	0.417	0.417
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.083	0.083	0.083	0.083	4.000
C-17A	0.083	0.083	0.083	0.083	CI
Starship	0.417	0.417	0.417	0.417	0.000
New Glenn	0.417	0.417	0.417	0.417	CR
					0.000

Figure 57: Alternative Future Europe 2040 - OPM (Simplicity)

The DM found simplicity to be a necessary priority in this alternative future and ranked the spacelift alternatives equally above the C-5M and C-17A. The importance of simplicity, or reducing the friction in the execution of logistics operations, is linked to the DM's finding of survivability as the most critical criterion. Contributing to the simplicity advantage is the key element of synchronized command and control empowered by spacelift's constant custody and in-transit visibility of the Quick Reaction Force. Effective command and control in this alternative future, enabled by spacelift's PTP capability, contributes to the unity of effort across the interagency. The DM's judgments were perfectly consistent.

Flexibility					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1/3	3	3	
C-17A	3	1	5	5	
Starship	1/3	1/5	1	1	
New Glenn	1/3	1/5	1	1	
Sum	4.667	1.733	10.000	10.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.214	0.192	0.300	0.300	0.252
C-17A	0.643	0.577	0.500	0.500	0.555
Starship	0.071	0.115	0.100	0.100	0.097
New Glenn	0.071	0.115	0.100	0.100	0.097
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.252	0.185	0.290	0.290	4.044
C-17A	0.755	0.555	0.484	0.484	CI
Starship	0.084	0.111	0.097	0.097	0.015
New Glenn	0.084	0.111	0.097	0.097	CR
					0.016

Figure 58: Alternative Future Europe 2040 - OPM (Flexibility)

The DM judged flexibility to be a desirable priority in this alternative future and ranked the C-17A above the C-5M and the spacelift alternatives. While the rapid loading and unloading of Rocket Cargo has been achieved with novel loadmaster designs and are comparable to airlift sequence of events, spacelift's responsiveness is a detriment to its ability to respond to unanticipated changes in highly dynamic environments. Once Rocket Cargo is launched, it has very limited capability to divert to an alternate landing zone. Airlift's far lower responsiveness gives it a decision-space advantage during mission execution. The DM slightly favors the C-17A over the C-5M for its airdrop capability and its ability to land on semi-prepared runways. The DM's judgments were highly consistent at 0.016.

Attainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1	1	
C-17A	1	1	1	1	
Starship	1	1	1	1	
New Glenn	1	1	1	1	
Sum	4.000	4.000	4.000	4.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.250	0.250	0.250	0.250	0.250
C-17A	0.250	0.250	0.250	0.250	0.250
Starship	0.250	0.250	0.250	0.250	0.250
New Glenn	0.250	0.250	0.250	0.250	0.250
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.250	0.250	0.250	0.250	4.000
C-17A	0.250	0.250	0.250	0.250	CI
Starship	0.250	0.250	0.250	0.250	0.000
New Glenn	0.250	0.250	0.250	0.250	CR
					0.000

Figure 59: Alternative Future Europe 2040 - OPM (Attainability)

The DM did not find attainability to be a priority in this alternative future. The DM's judgments were perfectly consistent.

Sustainability					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1	1	
C-17A	1	1	1	1	
Starship	1	1	1	1	
New Glenn	1	1	1	1	
Sum	4.000	4.000	4.000	4.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.250	0.250	0.250	0.250	0.250
C-17A	0.250	0.250	0.250	0.250	0.250
Starship	0.250	0.250	0.250	0.250	0.250
New Glenn	0.250	0.250	0.250	0.250	0.250
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.250	0.250	0.250	0.250	4.000
C-17A	0.250	0.250	0.250	0.250	CI
Starship	0.250	0.250	0.250	0.250	0.000
New Glenn	0.250	0.250	0.250	0.250	CR
					0.000

Figure 60: Alternative Future Europe 2040 - OPM (Sustainability)

The DM did not judge sustainability to be a priority for this alternative future. The DM's judgments were perfectly consistent.

Economy					
Overall Preference Matrix					
	C-5M	C-17A	Starship	New Glenn	
C-5M	1	1	1	1	
C-17A	1	1	1	1	
Starship	1	1	1	1	
New Glenn	1	1	1	1	
Sum	4.000	4.000	4.000	4.000	
Normalization					
	C-5M	C-17A	Starship	New Glenn	RVV (Alt)
C-5M	0.250	0.250	0.250	0.250	0.250
C-17A	0.250	0.250	0.250	0.250	0.250
Starship	0.250	0.250	0.250	0.250	0.250
New Glenn	0.250	0.250	0.250	0.250	0.250
					1.000
Consistency					
	C-5M	C-17A	Starship	New Glenn	λ max
C-5M	0.250	0.250	0.250	0.250	4.000
C-17A	0.250	0.250	0.250	0.250	CI
Starship	0.250	0.250	0.250	0.250	0.000
New Glenn	0.250	0.250	0.250	0.250	CR
					0.000

Figure 61: Alternative Future Europe 2040 - OPM (Economy)

The DM did not find economy to be a priority for this alternative future. The DM's judgments were perfectly consistent.

3.7.7 Summary

The Analytic Hierarchy Process has provided the DM a means to set a goal, evaluate alternatives given a complex set of criteria, extract quantifiable measures from their evaluations, create a common decision-making platform to effectively communicate with cross-functional teams, and execute their decision process systematically. The study of top-level strategic and planning guidance helps to organize a framework under which airlift and spacelift factors can be analyzed. The JP 4-0 Principles of Logistics has served as common criteria to evaluate both airlift and spacelift platforms. A thorough understanding of responsiveness, simplicity, flexibility, economy, attainability, sustainability, and survivability are crucial to systematically evaluating strategic lift alternatives against a common scenario.

In today's turbulent cycle of growing complexity, radical uncertainty, and rapid technological change, DoD DMs must possess the necessary skills and flexibility to adapt to unforeseen scenarios. Judging the utility of several types of platforms using criteria derived from top-level strategic guidance under a common alternative future allows DMs to move beyond conventional assumptions and positions. The organizations "best positioned to seize and incorporate the exploits of the new order will be those with the capability to perceive, learn, and adapt even when the signals from tomorrow may seem utterly ridiculous today" (Sotiriadis, 2020:2). While spacelift is still a maturing capability, its point-to-point utility in the execution of agile military logistics under several mission sets is palpable.

IV. Analysis and Results

4.1 Overview

The outcome of the AHP methodology is an Option Performance Matrix signifying the global priorities of the DM and a rank ordering of the alternatives, or the Value for Money Vector. There are six separate Value for Money Vectors representing the best strategic lift platforms in the context of six diverse alternative futures. These alternative futures represent a wide variety of required mission sets across an array of geographic areas of responsibility. While the analysis of each alternative future results in one of the four available strategic lift alternatives as the optimum platform, it must be explicitly recognized that Combatant Commanders would most likely choose a combination of platforms when executing real-world operations.

Acknowledging this, the purpose of this methodology is to aid the DM in systematically executing pairwise comparisons to accentuate the various strengths and weaknesses of each alternative against a specific mission set. The end result is to bring clarity to mission sets that favor unique spacelift capability versus air mobility taking into account the JP 4-0 Principles of Logistics and the various strengths and weaknesses associated with the four strategic lift alternatives. The AHP process and the DM's associated judgments are used in the following sections to develop a Model of Space Mobility Utility. The Model provides strategists a foundational resource of fundamental Space Mobility Factors to consider when framing the utility of spacelift as a strategic mobility option for the Combatant Commander.

4.2 Model of Space Mobility Utility

Salmi's (2020) Model of Air Mobility Utility provides the foundational structure in developing the Model of Space Mobility Utility (Figure 62). There are myriad air mobility factors that pertain to spacelift in the execution of PTP terrestrial logistics and the most pertinent are identified as Space Mobility Factors. To support USTRANSCOM's ability to achieve the Joint Force's supply requirements, the JP 4-0 Principles of Logistics can be factored into the spacelift planning process (CJCS, 2019b).

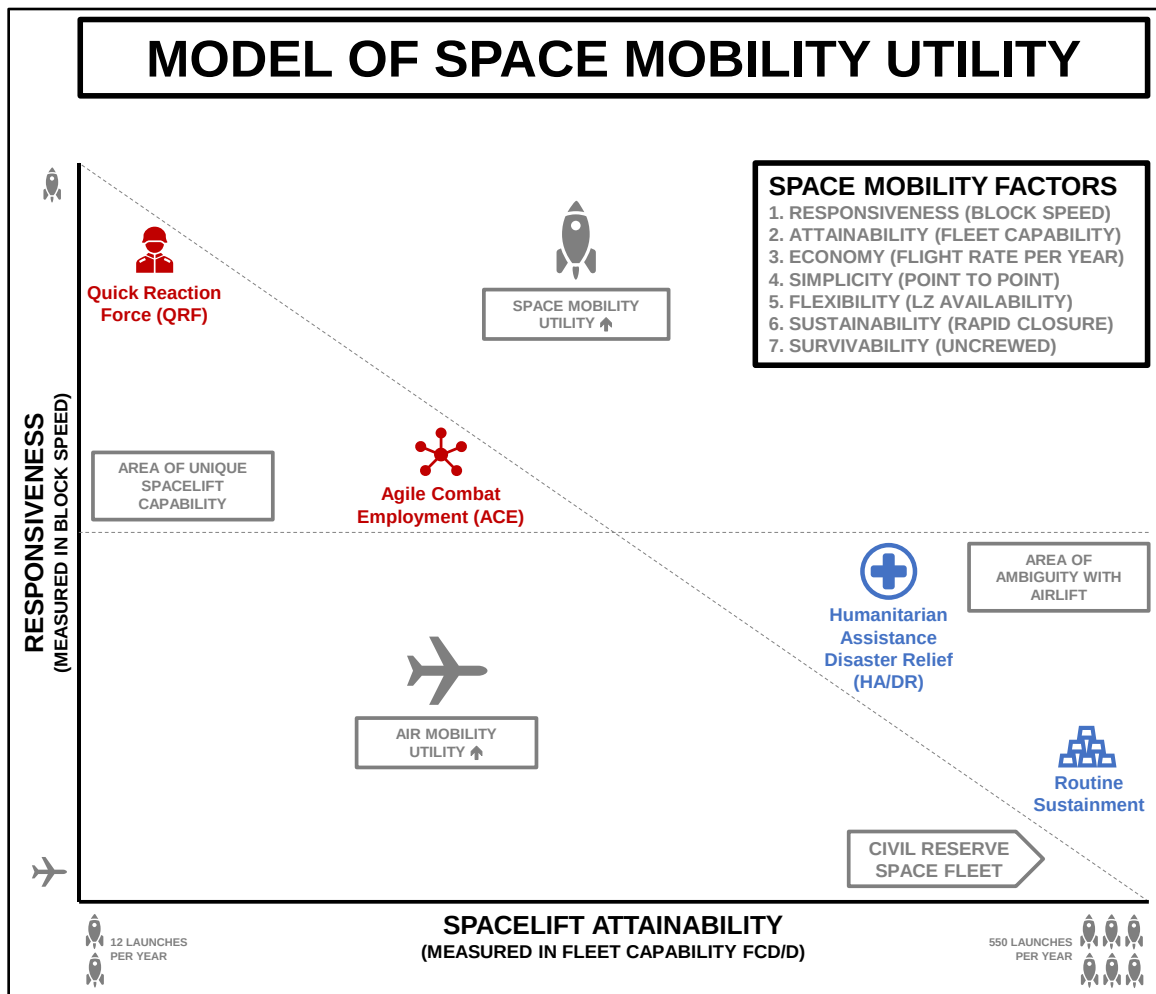


Figure 62: Model of Space Mobility Utility

The two primary Space Mobility Factors are responsiveness and attainability, measured respectively by block speed and fleet capability short tons delivered to the theater per day (FCD/D) (11). The principal differentiator between spacelift and other modes of transportation is its unmatched velocity. Akin to Salmi's description of aircraft, spacecraft are unrestricted by many of the constraints that plague other modes of transportation. In addition, its responsiveness is measured in minutes, not hours, days, or weeks. A spacecraft's notional ability to be reconstituted twelve times more than an aircraft in a twenty-four-hour period further adds to its responsiveness. This is attributed to a vastly increased utilization rate. Attainability is space mobility's greatest challenge as it has outsized implications across the range of Space Mobility Factors. A limited spacecraft fleet size precludes certain mission sets due to economic considerations and limits spacelift to an area of unique capability. Further increases in space mobility utility are reliant on a greater fleet capability that is projected to be 45 orders of magnitude beyond the area of unique spacelift capability. Enabling mission sets such as humanitarian assistance/disaster relief (HA/DR) and routine sustainment will most likely require 550 or more spacelift launches per year. This leads to outcomes such as a Civil Reserve Space Fleet type capability. The seven Space Mobility Factors depicted in the Model of Space Mobility Utility are presented in detail in Chapter III 3.3 Analytic Hierarchy Process Criteria. The most pertinent aspects of each of the seven factors are represented in the Model of Space Mobility Utility: block speed, fleet capability, flight rate per year, point to point, landing zone availability, rapid closure, and uncrewed.

The two factors of responsiveness and attainability form the basis for the four unique quadrants of the Model of Space Mobility Utility: area of unique spacelift

capability, area of ambiguity with air mobility, increased space mobility utility, and increased air mobility utility. The area of unique spacelift capability is characterized by exceptionally high responsiveness and relatively low spacelift fleet capability. This is represented by a spacelift platform whose commercialization has yet to completely mature. The two mission sets of Quick Reaction Force and Agile Combat Employment fall in this area of unique spacelift capability. The area of ambiguity with air mobility is distinguished by a competition between airlift and spacelift. This would develop, for example, as spacelift fleet capability continues to mature toward a Civil Reserve Space Fleet type capability. The two mission sets of HA/DR and routine sustainment fall in the area of ambiguity with air mobility. The area of focus for increased space mobility utility is characterized by a requirement for exceptionally high responsiveness. As this responsiveness requirement decreases, higher levels of attainability begin to dominate. The area of increased air mobility utility is distinguished by lower levels of responsiveness and a spacelift fleet capability that has yet to fully scale. In summary, the Model of Space Mobility Utility provides a framework for a Combatant Commander to conceptualize the utility of spacelift as a strategic mobility option. In addition, it loosely delineates the levels of responsiveness and attainability required for specific mission sets.

4.3 Results of Multiple-Criteria Decision Analysis

The AHP Option Performance Matrix aggregates the DMs qualitative judgments of the JP 4-0 Principles of Logistics against a specific alternative future (RVV Criteria) and the judgments of the four strategic lift alternatives against each of the seven Principles of Logistics (RVV Alternative). The Value for Money Vector (VMV) is the

sum-product of the RVV Criteria and the RVV Alternative. The gradient color coding helps the analyst to quickly ascertain which criteria and alternative is most important under a given alternative future; dark green represents the most important to light green which is insignificant and likewise for dark blue to light blue for the VMV. Figure 63 portrays each alternative future (highlighted in yellow) in the context of the Model of Space Mobility Utility with four scenarios in the area of unique spacelift capability and two scenarios in the area of ambiguity with airlift. Of note are two alternative futures that rely on a Civil Reserve Space Fleet type capability for mission accomplishment.

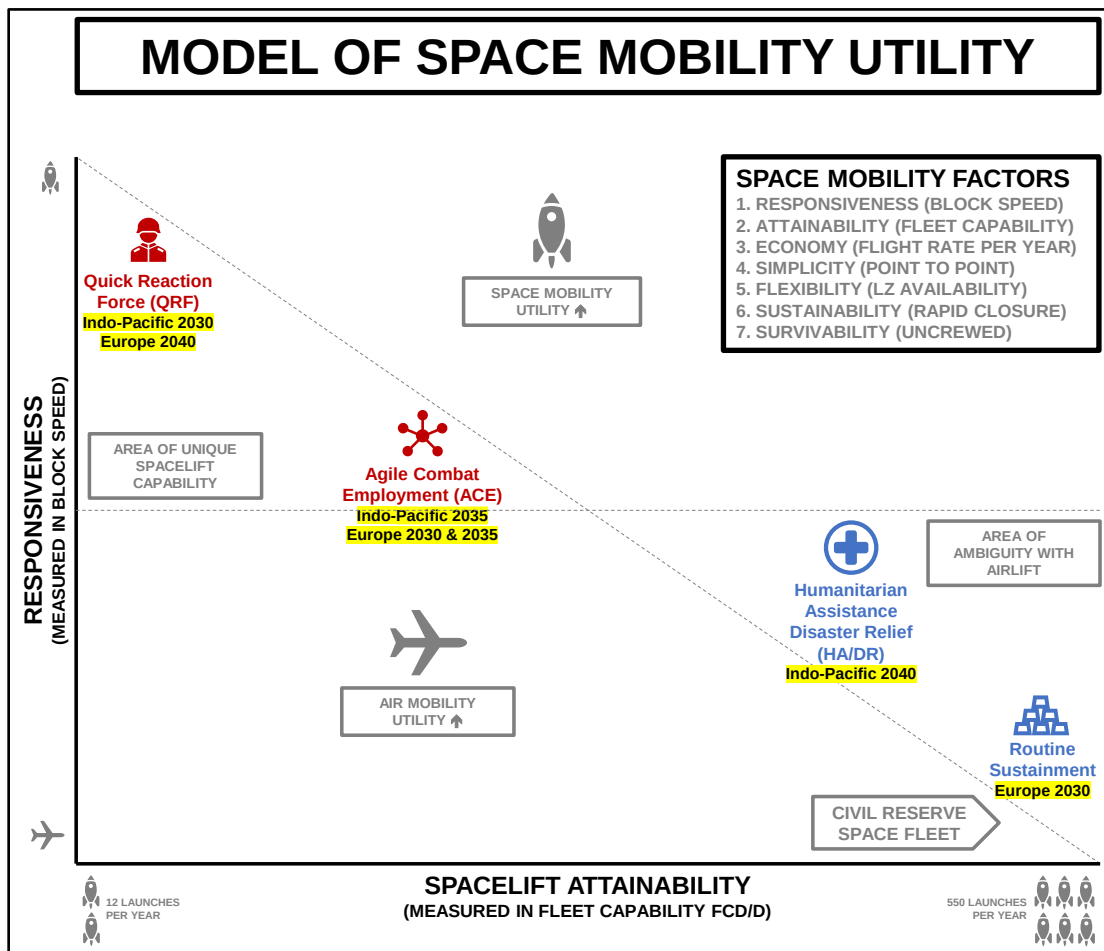


Figure 63: Alternative Futures on Model of Space Mobility Utility

4.3.1 Alternative Future Indo-Pacific 2030

Option Performance Matrix							
RVV (Crit)	0.392	0.139	0.093	0.027	0.058	0.039	0.252
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability
C-5M	0.056	0.263	0.201	0.253	0.552	0.285	0.049
C-17A	0.075	0.558	0.640	0.560	0.255	0.537	0.109
Starship	0.554	0.057	0.106	0.137	0.128	0.060	0.331
New Glenn	0.315	0.122	0.054	0.050	0.065	0.118	0.511
							Value for Money Vector
							1.000

Figure 64: Alternative Future Indo-Pacific 2030 - Option Performance Matrix

Alternative Future Indo-Pacific 2030 is a Quick Reaction Force mission and is represented in the Model of Space Mobility Utility's area of unique spacelift capability. The DM judged the Starship strategic spacelift alternative as best suited to fulfill the significant criteria of responsiveness, survivability, simplicity, and flexibility. The DM found responsiveness to be a highly critical characteristic for strategic lift platforms in this alternative future given the tyranny of distance, weighing in at almost equivalent importance when compared to the next two criteria of survivability and simplicity. The DM slightly favoring the Starship over the New Glenn provided a decisive advantage in this alternative future. Judging both platforms with equal importance in responsiveness shifts the overall preference to the New Glenn, however, the Starship's higher capacity and ability to deliver all materiel in one sortie definitively delivers higher value to the Combatant Commander in the responsiveness category. The C-17A scored high in the areas of simplicity, flexibility, economy, and sustainability but the DM only judged simplicity and flexibility to be significant criteria in this alternative future. As the alternative future progresses, it is conceivable that survivability will overtake responsiveness in greatest importance to the DM which would potentially make the New Glenn the preferred alternative.

4.3.2 Alternative Future Indo-Pacific 2035

Option Performance Matrix								
RVV (Crit)	0.126	0.035	0.257	0.038	0.110	0.080	0.355	Value for Money
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	Vector
C-5M	0.089	0.240	0.139	0.245	0.536	0.261	0.051	0.162
C-17A	0.044	0.544	0.064	0.581	0.261	0.525	0.105	0.171
Starship	0.597	0.066	0.375	0.047	0.140	0.090	0.315	0.310
New Glenn	0.270	0.150	0.422	0.127	0.063	0.124	0.529	0.357
								1.000

Figure 65: Alternative Future Indo-Pacific 2035 - Option Performance Matrix

Alternative Future Indo-Pacific 2035 is an Agile Combat Employment mission and is characterized in the Model of Space Mobility Utility's area of unique spacelift capability. The DM found the New Glenn strategic spacelift alternative as best suited to fulfill the significant criteria of survivability, flexibility, responsiveness, attainability, and sustainability. The DM judged survivability to be a highly critical characteristic for strategic lift platforms in this alternative future given the widespread A2/AD threats in the region. The DM judged survivability to be approximately 50% more important than flexibility which was an essential priority to support the dynamic basing construct in the region. The DM judging the New Glenn's survivability capability as slightly more important than Starship's provided an adequate advantage in this alternative future. Judging both spacelift platforms with equal importance in survivability would shift the overall preference to the Starship since it has a decisive advantage in responsiveness, the third most important criteria in this alternative future. Due to the tyranny of distance in the Indo-Pacific, the A2/AD threats in the region, and the logistics requirements of dynamic and dispersed basing, the two airlift alternatives did not score well. As the alternative future progresses, it is conceivable that sustainability will overtake survivability and responsiveness in greater importance to the DM which would potentially make the C-17A the preferred alternative.

4.3.3 Alternative Future Indo-Pacific 2040

Option Performance Matrix								Value for Money Vector
RVV (Crit)	0.053	0.098	0.046	0.135	0.340	0.297	0.031	
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	
C-5M	0.113	0.545	0.351	0.528	0.242	0.492	0.250	0.383
C-17A	0.047	0.258	0.351	0.260	0.495	0.311	0.250	0.348
Starship	0.585	0.141	0.189	0.151	0.177	0.071	0.250	0.163
New Glenn	0.255	0.056	0.109	0.062	0.086	0.126	0.250	0.107
								1.000

Figure 66: Alternative Future Indo-Pacific 2040 - Option Performance Matrix

Alternative Future Indo-Pacific 2040 is a HA/DR mission and is represented in the Model of Space Mobility Utility's area of ambiguity with airlift. The DM judged the C-5M strategic airlift alternative as best suited to fulfill the significant criteria. The DM found attainability and sustainability to be highly critical characteristics for strategic lift platforms in this alternative future given the immediate and long-term humanitarian supply requirements in the region. The DM judged both attainability and sustainability as overwhelming priorities in this alternative future, balancing the need to both deliver immediate life-saving supplies and sustain a long-term logistics operation. The DM judged the C-17A as the top alternative to achieve attainability due to its airdrop capability but was outranked by the C-5M in both sustainability and economy. The C-5M was only slightly favored over the C-17A in sustainability and economy; if they were ranked with equal importance, the C-17A would have been the preferred alternative. Although the CRSF was activated in this alternative future, both spacelift alternatives simply could not support many of Akiyama's required outsized rolling stock. The damage caused by the magnitude nine earthquake also precluded many of the available rocket landing zones. It is conceivable that spacelift would be ranked more favorably as the alternative future progresses with increased repairs to infrastructure.

4.3.4 Alternative Future Europe 2030

Option Performance Matrix								
RVV (Crit)	0.323	0.037	0.110	0.025	0.214	0.182	0.109	Value for Money
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	Vector
C-5M	0.350	0.248	0.085	0.242	0.359	0.308	0.109	0.282
C-17A	0.438	0.550	0.536	0.576	0.428	0.515	0.189	0.441
Starship	0.152	0.144	0.227	0.045	0.155	0.122	0.351	0.174
New Glenn	0.060	0.058	0.152	0.137	0.057	0.055	0.351	0.102
								1.000

Figure 67: Alternative Future Europe 2030 - Option Performance Matrix

Alternative Future Europe 2030 is both an Agile Combat Employment and Routine Sustainment mission and is represented in the Model of Space Mobility Utility's areas of unique spacelift capability and area of ambiguity with airlift. The DM found the C-17A strategic airlift alternative as best suited to fulfill the significant criteria. The DM judged responsiveness to be a highly critical characteristic for strategic lift platforms in this alternative future given the requirement to rapidly reinforce the eastern flank of the alliance. The DM judged responsiveness with equivalent importance to the next two essential priorities of attainability and sustainability, which are critical to empower the Joint Force to initiate operations at an acceptable level of risk and to sustain long-term objectives. With the DM choosing the C-17A as the top alternative for six of the seven Principles of Logistics, it was the overwhelming favorite in this alternative future. The C-17A's ability to airdrop the Immediate Response Force, unmatched surge UTE rate, and large fleet size provided it a clear advantage over the C-5M and two spacelift alternatives. The Starship and New Glenn could deliver revolutionary capabilities in this alternative future; however, fleet size is a limiting factor with only twelve platforms on alert posture. As the alternative future progresses and increasing amounts of outsized cargo is required, the C-5M will play a crucial role in transporting heavy equipment and increasing overall cargo throughput.

4.3.5 Alternative Future Europe 2035

Option Performance Matrix								
RVV (Crit)	0.248	0.361	0.029	0.045	0.152	0.107	0.057	Value for Money
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	Vector
C-5M	0.088	0.074	0.392	0.311	0.071	0.172	0.250	0.118
C-17A	0.074	0.145	0.279	0.434	0.141	0.070	0.250	0.142
Starship	0.235	0.415	0.165	0.116	0.520	0.416	0.250	0.356
New Glenn	0.603	0.366	0.165	0.139	0.268	0.341	0.250	0.384
								1.000

Figure 68: Alternative Future Europe 2035 - Option Performance Matrix

Alternative Future Europe 2035 is an Agile Combat Employment mission and is represented in the Model of Space Mobility Utility's area of unique spacelift capability. The DM judged the New Glenn strategic spacelift alternative as best suited to fulfill the significant criteria of simplicity, responsiveness, attainability, and sustainability. The DM found simplicity to be a highly critical characteristic for strategic lift platforms in this alternative future given the significant command and control synchronization, in-transit visibility of cargo, and unity of effort required to resupply the Arctic. The DM evaluated simplicity and responsiveness to account for more than half the weighted judgments across all seven Principles of Logistics. The New Glenn and Starship, with VMVs of 0.384 and 0.356, were weighted similarly by the DM. Slight changes in the weighting of the two spacelift platforms against the criteria of simplicity or responsiveness will have consequential impacts on the priority platform chosen. The two strategic airlift alternatives scored well in the criteria of economy and flexibility; however, those two criteria were deemed insignificant. The geographical requirements in this alternative future plays an outsized role in the DM's judgments driving a high priority placed on PTP resupply capability and landing zone availability. Strategic airlift will play a crucial role in pre-positioning cargo to the spaceports for launch.

4.3.6 Alternative Future Europe 2040

Option Performance Matrix								
RVV (Crit)	0.197	0.121	0.087	0.031	0.031	0.031	0.502	Value for Money
RVV (Alt)	Responsiveness	Simplicity	Flexibility	Economy	Attainability	Sustainability	Survivability	Vector
C-5M	0.054	0.083	0.252	0.250	0.250	0.250	0.125	0.129
C-17A	0.114	0.083	0.555	0.250	0.250	0.250	0.125	0.167
Starship	0.506	0.417	0.097	0.250	0.250	0.250	0.375	0.370
New Glenn	0.326	0.417	0.097	0.250	0.250	0.250	0.375	0.334
								1.000

Figure 69: Alternative Future Europe 2040 - Option Performance Matrix

Alternative Future Europe 2040 is a Quick Reaction Force mission and is represented in the Model of Space Mobility Utility's area of unique spacelift capability. The DM found the Starship strategic spacelift alternative as best suited to fulfill the significant criteria of survivability, responsiveness, simplicity, and flexibility. The DM judged survivability to be a highly critical characteristic for strategic lift platforms in this alternative future given the requirement to insert a Quick Reaction Force into the diplomatic compound. The DM found survivability to account for more than half of the overall weight when compared to the other six Principles of Logistics. The DM ranked both the Starship and New Glenn equally survivable in this alternative future which made the performance of both platforms crucial under the criteria of responsiveness, simplicity, and flexibility. The DM judged the Starship to be slightly more important than the New Glenn in terms of responsiveness due to its capacity advantage and ability to transport all requirements in one sortie; should payload requirements change, the New Glenn could be weighted higher in terms of responsiveness. The two spacelift platforms scored equally in the criteria of simplicity and flexibility and therefore were not factors between the Starship and the New Glenn. Because of the highly unique nature of the mission, the two airlift alternatives simply did not factor into the DM's calculus.

4.4 Investigative Questions Answered

To support the Joint Force’s ability to move and maneuver, what air mobility criteria can a DM apply to space mobility for PTP logistics? A review of top-level air mobility and logistics-focused strategic and planning guidance illuminates the criteria that best articulate the most pertinent factors of space mobility in the context of agile PTP logistics. With exception to air mobility variables directly involving aircrews and passengers such as medical, stage crews, and crew ratios, the air mobility criteria listed in Appendix B are applicable to space mobility. In the interest of condensing these criteria for pairwise comparisons in the AHP, the seven Principles of Logistics of JP 4-0 deliver the fundamental direction to plan, execute, and assess Joint logistics operations and provide the baseline for other top-level air mobility and logistics-focused guidance (Table 5). The seven factors of responsiveness, simplicity, flexibility, economy, attainability, sustainability, and survivability serve as primary criteria for evaluating alternatives in this research and are pertinent factors for a Combatant Commander to consider regardless of mode selection. Planning factors found in CJCS JP 3-17, AFDP 3-36, Salmi’s Model of Air Mobility Utility, Prevett and Anderson’s Table of Modality Decision Criteria, the Algebra of Airlift, and AFPAM 10-1403 were interconnected with the seven Principles of Logistics in the context of an analysis of alternatives (Section III 3.3 Analytic Hierarchy Process Criteria). Salmi’s Model of Air Mobility Utility was crucial to balancing the competing factors of responsiveness (velocity and capacity), attainability, and sustainability. Brigantic and Merrill’s Algebra of Airlift and the related AFPAM 10-1403, *Air Mobility Planning Factors*, reinforced the qualitative Principles of Logistics with quantitative formulas, particularly the equations

for productivity (9), million ton-miles per day (MTM/D) (10), fleet capability short tons delivered to the theater per day (FCD/D) (11), number of missions required (12), and closure (13).

What is the relative importance of such criteria (i.e., what is the value to the DM) under a given scenario? Section III 3.7 Data Description and Analysis represents steps 5-8 of the AHP and serves as a detailed analysis of the DM's judgments of the Principles of Logistics in the context of each of the six 3.6 Analytic Hierarchy Process Alternative Futures. Section IV 4.3 Results of provides a synopsis of these judgments in the Option Performance Matrix (RVV Criteria). The following is a list of figures that represent the DM's pairwise comparisons and resulting Relative Value Vector of Criteria:

Figure 14: Alternative Future Indo-Pacific 2030 - OPM (Main Criteria)

Figure 22: Alternative Future Indo-Pacific 2035 - OPM (Main Criteria)

Figure 30: Alternative Future Indo-Pacific 2040 - OPM (Main Criteria)

Figure 38: Alternative Future Europe 2030 - OPM (Main Criteria)

Figure 46: Alternative Future Europe 2035 - OPM (Main Criteria)

Figure 54: Alternative Future Europe 2040 - OPM (Main Criteria)

What is the relative importance of each alternative with respect to each criterion under a given scenario? Section III 3.7 Data Description and Analysis represents step 9 of the AHP and serves as a detailed analysis of the DM's judgments of the four strategic lift alternatives under each of the seven Principles of Logistics. Section IV 4.3 Results of provides a synopsis of these judgments in the Option Performance Matrix (RVV Alternative).

Which alternative is the preferred given criteria and alternative preferences?

Section IV 4.3 Results of represents step 10 of the AHP and delivers the Option Performance Matrix of the DM's judgments of the four strategic lift alternatives in the context of each of the seven Principles of Logistics given a specific alternative future. The preferred alternative is represented in the Value for Money Vector. The following is a list of figures that represent the six Option Performance Matrices:

Figure 64: Alternative Future Indo-Pacific 2030 - Option Performance Matrix

Figure 65: Alternative Future Indo-Pacific 2035 - Option Performance Matrix

Figure 66: Alternative Future Indo-Pacific 2040 - Option Performance Matrix

Figure 67: Alternative Future Europe 2030 - Option Performance Matrix

Figure 68: Alternative Future Europe 2035 - Option Performance Matrix

Figure 69: Alternative Future Europe 2040 - Option Performance Matrix

What DoD mobility missions are uniquely enabled by spacelift? What are some drawbacks to utilizing spacelift for the mobility mission? The Model of Space Mobility Utility (Figure 62) showcases the DoD mobility missions that are uniquely enabled by spacelift irrespective of spacelift attainability, or the maturity of the commercial spacelift industry. Alternative Futures Indo-Pacific 2030 and Europe 2040 required a Quick Reaction Force-type mission and Alternative Futures Indo-Pacific 2035 and Europe 2035 required the execution of Agile Combat Employment (Figure 63). These four mission sets fall squarely in the area of unique spacelift capability where responsiveness, measured by block speed, is a crucial requirement and where attainability is largely irrelevant. The Starship was judged to be the best alternative in both Alternative Futures Indo-Pacific 2030 and Europe 2040 and the New Glenn was found to be the best

alternative in both Alternative Futures Indo-Pacific 2035 and Europe 2035. The Space Mobility Factors identified in this research and highlighted in Section III 3.3 Analytic Hierarchy Process Criteria shed light on the potential drawbacks to utilizing spacelift for the mobility mission.

4.5 Summary

The analysis and results provide an avenue toward a theory of space mobility through the methodical pairwise comparison process of the AHP which highlights the various strengths and weaknesses of each strategic lift platform against specific mission sets in six diverse alternative futures. The Model of Space Mobility Utility and its seven associated factors synthesize the efficacy of two existing airlift platforms and two notional spacelift platforms across the continuum of attainability and responsiveness.

Air mobility criteria identified from top-level strategic guidance is selectively applied to the utility of space mobility for PTP logistics to support the Joint Force's ability to move, maneuver, and receive resupply. The relative importance of such criteria is identified to ascertain the value to the Combatant Commander in the context of specific mission sets. The Model of Space Mobility Utility highlights DoD missions that are uniquely enabled by spacelift. It also identifies other missions where the preference between spacelift and traditional airlift is ambiguous. Finally, the Combatant Commander is further empowered by the identification of seven Space Mobility Factors that shed light on the potential strengths and weaknesses in utilizing spacelift for the mobility mission.

V. Conclusions and Recommendations

5.1 Conclusions of Research

A Model of Space Mobility Utility was derived using the multi-criteria decision analysis methodology of the Analytic Hierarchy Process. Considering criteria from top-level strategic and planning guidance, a set of Space Mobility Factors was identified and thoroughly analyzed. The Model and associated Factors provides future strategists a foundational resource to consider when framing the utility of spacelift as a strategic mobility option for the Combatant Commander.

This research leverages the Global Mobility Enterprise to enable spacelift for point-to-point cargo delivery by applying air mobility-focused Principles of Logistics to space mobility. Methodical pairwise comparisons between the four strategic lift alternatives in the context of several alternative futures illuminates the interconnectedness between qualitative and quantitative airlift and spacelift factors. The Model's synthesis of the efficacy of each platform type across the continuum of attainability and responsiveness highlights both missions that are uniquely enabled by spacelift and those for which the preference between spacelift and airlift is ambiguous.

5.2 Significance of Research

A near-peer conflict with the United States' two primary pacing threats of China and Russia will involve contested logistics, particularly in the non-permissive U.S. Indo-Pacific Command area of responsibility, where the tyranny of distance will significantly amplify the challenges associated with moving, maneuvering, and sustaining the Joint Force. Rocket Cargo, or point-to-point terrestrial spacelift, promises to upend airlift's

position atop the Strategic Mobility Triad as the Combatant Commander's most expeditious method of strategic lift. The commercial space launch industry's rapid development of the most capable rockets in history and the pursuit of similar technology by adversaries brings a sense of urgency in preparing the DoD to be an early adopter.

This research adds to existing work by AFRL's Vanguard program and multiple USTRANSCOM CRADAs with several industry partners. The Model of Space Mobility Utility empowers decision-makers with use case clarity for a capability that has yet to be fielded but one that is strongly funded, studied, and pursued by the USAF. The use of spacelift for point-to-point terrestrial logistics may have deeply transformative impacts on the conduct of warfare.

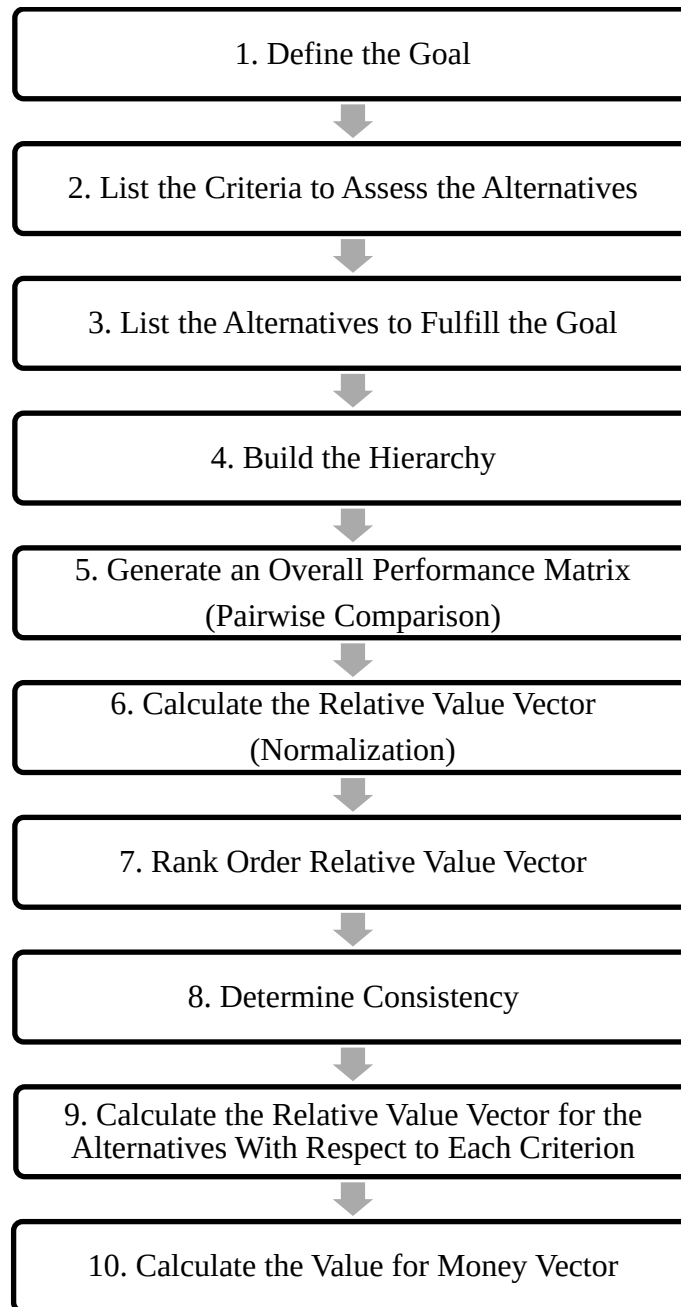
5.3 Recommendations for Action and Future Research

Future strategists of space mobility would benefit from applying the methodical steps of the Capabilities-Based Assessment of the Joint Capabilities Integration and Development System when building upon this research. One particular focus area should be on identifying relevant expertise to wargame the application of the Model of Space Mobility Utility against classified Defense Planning Scenarios.

The logistics enterprise should develop an Algebra of Spacelift, or Space Mobility Planning Factors, as an equivalent to AFPAM 10-1403 to assist future strategists in quantitative decision-making with respect to employing point-to-point terrestrial spacelift. Finally, future research can compare a wider array of strategic lift platforms and approach the decision analysis using inputs from DoD senior leaders in the logistics enterprise to inform a Value-Focused Thinking decision analysis.

Appendix A

AHP Process Flow Chart



Appendix B

Air Mobility Criteria

Guidance	Criteria
JP 4-0, Joint Logistics (CJCS, 2019b:I-8-9)	Responsiveness Simplicity Flexibility Economy Attainability Sustainability Survivability
JP 3-17, Air Mobility Operations (CJCS, 2019a:III-1-20)	Marshalling Intelligence Vulnerabilities and Threats Communications Systems Sustainment Assessment Multinational Planning Considerations Other Planning Factors
AFDP 3-36, Air Mobility Operations (USAF, 2019:30-34)	Partner Nation Support Access Communications Base Operating Support Airspace Control Diplomatic Clearances Legal Issues (Principles of International Law) Medical Multimodal Ports and Hubs Geography Climatology and Weather ISR Threat Working Group Threat Mitigation
Air Mobility Utility Model (Salmi, 2020:2-23)	Velocity Capacity Attainability Sustainability Freedom of Movement Air Superiority Access Command and Control C2 Operational Responsibility C2 Support Responsibility

	Integrated Logistics Technology Training Individual-Focused Training Group-Focused Training
Table of Modality Decision Criteria (Prevelt and Anderson, 2017:16)	Costs Monetary Considerations Security Considerations Geography Distance to be Moved Location of the Port Weather Considerations Operational Higher Headquarters Taskings Mission Type Standard Operating Procedure Time Phased Deployment Layout Political Leader's Preferences Host Nation Sensitivities Inflated Requirements Organizational Bias System Knowledge Trust Visibility in the System System Cargo Handling Limitations at the Port Cargo Type Load Efficiency Platform Availability Speed of Delivery Volume of Cargo Time Advanced Notice Criticality Emerging Requirements Force Flow Model Force Provider Availability Late Requests
Algebra of Airlift (Brigantic and Merrill, 2004) & AFPAM 10-1403, Air Mobility Planning Factors (USAF, 2018)	Number of Cargo Missions Number of Passenger Missions Total Missions Required Round Trip Flying Time (RTFT) Average Block Speed

Total Ground Time
Cycle Time
Station Interval
Aircraft Allocation Interval
Flying Hour Capability Interval
Stage Crew Interval
Flow Interval
Closure
Maximum on the Ground (Parking)
Maximum on the Ground (Working)
Required Aircraft
Tons Per Day
Number of Stage Crews Needed
Total Crews required
Crew Ratio Required
Utilization (UTE) Rate
Average Aircraft on Station
Productivity Factor
Million Ton Miles Per Day (MTM/D)
Scenario Use Rate
Objective Utilization (UTE) Rate
Primary Mission Aerospace Vehicle
Inventory (PMAI)
Total Active Inventory (TAI)
Mission Capable (MC) Rate
Non-Mission Capable (NMC) Rate

Bibliography

Air Force Research Laboratory (AFRL). “Rocket Cargo Vanguard Path Forward.” Report to SAF, HQ USAF, Washington DC. May 2021.

Air Mobility Command (AMC). “FY 2021 Charter Guidance and Rates for Special Assignment Airlift Missions, Joint Exercise Transportation Program, and Contingency Missions for the Transportation Working Capital Fund.” Report to USTRANSCOM, HQ USTRANSCOM, Scott AFB IL. 30 September 2021.

Airlift App. Version 1.0, Lt Col Adam Reiman, Windows, file. Computer software. Air Force Institute of Technology, Wright-Patterson AFB OH, 2021.

Berry, Warren. “Air Force Persistent Logistics Sustaining Combat Power during 21st Century Competition and Conflict,” *The Mitchell Forum*, 37: 1-10 (December 2020).

“Blue Origin New Glenn.” *BlueOrigin.com*. Blue Origin, LLC. December 2021. Retrieved on 4 December 2021.

“Blue Origin Record of Safety.” *BlueOrigin.com*. Blue Origin, LLC. January 2022. Retrieved on 1 January 2022.

Brigantic, R.T. and D. Merrill. “The Algebra of Airlift,” *Mathematical and Computer Modelling*, 39: 649–656 (March 2004).

Brown, Charles Q., “CSAF Action Orders to Accelerate Change Across the Air Force.” AF.mil. 10 December 2020. Retrieved on 5 September 2021.

“C-17 Globemaster III.” *Boeing.com*. The Boeing Company. December 2021. Retrieved on 28 December 2021.

“C-5M Super Galaxy.” *LockheedMartin.com*. Lockheed Martin Corporation. December 2021. Retrieved on 28 December 2021.

Chairman of the Joint Chiefs of Staff (CJCS). *Capabilities-Based Assessment (CBA) User’s Guide Version 3*. CBA. Washington: CJCS, March 2009.

Chairman of the Joint Chiefs of Staff (CJCS). *Joint Concept for Logistics*. JCL. Washington: CJCS, 25 September 2015.

- Chairman of the Joint Chiefs of Staff (CJCS). *Joint Publication 3-17 Air Mobility Operations*. JP 3-17. Washington: CJCS, 5 February 2019a.
- Chairman of the Joint Chiefs of Staff (CJCS). *Joint Publication 4-0 Joint Logistics*. JP 3-17. Washington: CJCS, 8 May 2019b.
- Chairman of the Joint Chiefs of Staff (CJCS). *Joint Publication 4-01 The Defense Transportation System*. JP 4-01. Washington: CJCS, 18 July 2017.
- Coyle, Geoff. *Practical Strategy: Structured Tools and Techniques*. New York: Pearson College Division, 2004.
- Dillon-Merrill, Robin, Gregory S. Parnell, Donald L. Buckshaw, and William R. Hensley. "Avoiding Common Pitfalls in Decision Support Frameworks for Department of Defense Analyses," *Military Operations Research*, 13: 19-31 (March 2008).
- "Dueling Superpowers, Rival Billionaires. Inside the New Race to the Moon." *Time.com*. Time Magazine. July 2019. Retrieved on 16 January 2022.
- Erwin, Sandra, "SpaceX wins \$102 million Air Force contract to demonstrate technologies for point-to-point space transportation." *SpaceNews.com*. 19 January 2022. Retrieved on 20 January 2022.
- Federal Aviation Administration (FAA). *The Annual Compendium of Commercial Space Transportation: 2018*. Washington: Bryce Space and Technology, 2018.
- Harper, Jon, "Space Force Dreams of Using Rockets to Supply Warfighters." *NationalDefenseMagazine.org*. 13 August 2021. Retrieved on 2 September 2021.
- Hellman, Barry M., John E. Bradford, Brad D. St Germain, and Kevin Feld. "Global Humanitarian Supply Delivery with Reusable Launch Vehicles," *AIAA Space Forum*, 15: 1-11 (August 2015).
- Ho, William and Xin Ma. "The state-of-the-art integrations and applications of the analytic hierarchy process," *European Journal of Operational Research*, 267: 399-414 (June 2018).
- Ishizaki, Alessio and Markus Lusti. "How to derive priorities in AHP: a comparative study," *Central European Journal of Operations Research*, 14: 387-400 (November 2006).

- Jackson, Jack A., Brian L. Jones, and Lee J. Lehmkuhl. *An Operational Analysis for Air Force 2025: An Application of Value-Focused Thinking to Future Air and Space Capabilities* MS thesis, ACSC. Air Command and Staff College, Air War College (AU), Maxwell AFB AL, May 1996 (AD-A392587).
- Jones, Andrew, “China launches secretive suborbital vehicle for reusable space transportation system.” SpaceNews.com. 16 July 2021. Retrieved on 3 September 2021.
- Jurist, John M., David Livingston, David C. Hook, James R. Wertz, Robert Conger, and Thomas Bauer. “Small Unit Space Transport and Insertion (SUSTAIN).” Report to National Security Space Office, Pentagon, Washington DC. January 2009.
- Jurk, David M. *Decision Analysis with Value Focused Thinking as a Methodology to Select Force Protection Initiatives for Evaluation*. MS thesis, AFIT/GEE/ENV/02M-05. Graduate School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 2002 (AD-A400708).
- Keeney, Ralph. “Applying Value-Focused Thinking,” *Military Operations Research*, 13: 7-17 (March 2008).
- Koether, Stephen J. *Rapid Global Mobility Through Space*. MS thesis, AFIT/ENS/MS/18-J-033. Graduate School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, June 2018 (AD-1068864).
- Kwast, Steven L. *Fast Space: Leveraging Ultra Low-Cost Space Access for 21st Century Challenges*. Maxwell AFB AL: Air University, December 2016.
- Liberatore, Matthew J. and Tan Miller. “A Decision Support Approach for Transport Carrier and Mode Selection,” *Journal of Business Logistics*, 16: 85-115 (January 1995).
- Magidson, Daniel J. Deputy Chief, Logistics Readiness Division, Air Mobility Command, Scott AFB IL. Personal Interview. 11 Feb 2022.
- Maywald, Jacob, Adam Reiman, Alan W. Johnson, and Robert E. Overstreet. “The Myth of Strategic and Tactical Airlift,” *Air and Space Power Journal*, 31: 61-71 (March 2017).

Merrill, Dave. “Understanding the MTM/D Mobility Metric.” Report to AMC, HQ AMC, Scott AFB IL. 4 December 2013.

Mills, Patrick, James A. Leftwich, John G. Drew, Daniel P. Felten, Josh Girardini, John P. Godges, Michael J. Lostumbo, Anu Narayanan, Kristin Van Abel, Jonathan Welburn, and Anna Jean Wirth. *Building Agile Combat Support Competencies to Enable Evolving Adaptive Basing Concepts*. Contract RR-4200-AF. Santa Monica CA: RAND Corporation, September 2017.

National Defense Transportation Association (NDTA), “Van Ovost Confirmed as Next USTRANSCOM Commander.” NDTAHQ.com. 5 October 2021. Retrieved on 30 October 2021.

“New Glenn Payload User’s Guide Revision C.” *BlueOrigin.com*. Blue Origin, LLC. October 2018. Retrieved on 8 November 2021.

Office of the Secretary of Defense (OSD). *Military and Security Developments Involving the People’s Republic of China*. Annual Report to Congress. Washington: OSD, 2020.

Office of the Secretary of Defense (OSD). *Summary of the 2018 National Defense Strategy of the United States of America*. Washington: OSD, 2018.

Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD/A&S). *Joint Deployment and Distribution Enterprise (JDDE) Planning and Operations*. DODI 5158.06. Washington: OUSD/A&S, April 2020.

Office of the Under Secretary of Defense for Research and Engineering (OUSD/R&E). *Final Report of the Defense Science Board (DSB) Task Force on Survivable Logistics – Executive Summary*. Washington: OUSD/R&E, November 2018.

Olson, John M., Steven J. Butow, Eric Felt, Thomas Cooley, and Joel B. Mozer, “State of the Space Industrial Base 2021 Infrastructure & Services for Economic Growth & National Security.” DIU.mil. November 2021. Retrieved on 2 December 2021.

Owen, Robert C. *Strategic Air Mobility Forces for Future Relevance*. Maxwell AFB AL: Air Force Research Institute, January 2017 (AD-1030221).

Parnell, Gregory S., Jack A. Jackson, Roger C. Burk, Lee J. Lehmkuhl, and Joseph A. Engelbrecht, Jr. “R&D Concept Decision Analysis: Using Alternate Futures for Sensitivity Analysis,” *Journal of Multi-Criteria Decision Analysis*, 8: 119-127 (May 1999).

- Peltier, C. China's Logistics Capabilities for Expeditionary Operations. Washington: China Economic and Security Review Commission, April 2020.
- Prevett, Tyler T. *Sealift or Airlift for Global Mobility?* MS thesis, AFIT/IMO/ENS/06E-15. Graduate School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, May 2007.
- Prevett, Tyler T. and Bradley E. Anderson. "Using an analytic network process model to incorporate qualitative factors into multi-criteria global modal choice decisions," *Journal of Transportation Management*, 27: 7-21 (January 2017).
- Saaty, Thomas L. "Axiomatic Foundation of the Analytic Hierarchy Process," *Management Science*, 32: 841-855 (July 1986).
- Saaty, Thomas L. "Decision-making with the AHP: Why is the principal eigenvector necessary," *European Journal of Operational Research*, 145: 85-91 (January 2003).
- Saaty, Thomas L. "How to make a decision: The Analytic Hierarchy Process" *European Journal of Operational Research*, 48: 9-26 (September 1990).
- Saaty, Thomas L. "Relative Measurement and Its Generalization in Decision Making: Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors – The Analytic Hierarchy/Network Process," *Statistics and Operations Research*, 102: 251-318 (January 2008).
- Saaty, Thomas L. "Response to Holder's Comments on the Analytic Hierarchy Process," *The Journal of the Operational Research Society*, 42: 909-914 (October 1991).
- Saaty, Thomas L. "The analytic hierarchy process – what it is and how it is used," *Mathematical Modeling*, 9: 161-176 (1987).
- Salmi, Derek M. *Behind the Light Switch: Toward a Theory of Air Mobility*. Maxwell AFB AL: Air University, August 2020 (AD-1127925).
- Secretary of the Air Force Public Affairs (SAF/PA), "Department of the Air Force announces fourth Vanguard program." AF.mil. 4 June 2021. Retrieved on 2 September 2021.
- "Side Boosters Have Landed." *NASA.gov*. National Aeronautics and Space Administration. June 2019. Retrieved on 4 December 2021.

- Solen, Derek. "The PLA's Critical Assessment of the Agile Combat Employment Concept," *China Brief*, 21, 12-16 (July 2021).
- Sotiriadis, Jacob S., and Jairus V. Grove. "Global Futures Report: Alternative Futures of Geopolitical Competition in a Post COVID-19 World." Report to Air Force Warfighting Integration Capability (AFWIC) Strategic Foresight and Futures Branch, HQ USAF, Pentagon, Arlington VA. June 2020.
- "Starship Update." *SpaceX.com*. Space Exploration Technologies. February 2022. Retrieved on 10 February 2022.
- "Starship Users Guide Revision 1.0." *SpaceX.com*. Space Exploration Technologies. March 2020. Retrieved on 22 August 2021.
- SuperDecisions. Version 3.2, Decision Lens Inc., Windows, file. Computer software. Creative Decisions Foundation, Pittsburgh PA, 2021.
- Temucin, Tolga. "Multi-Criteria Decision Making: A Cast Light Upon the Usage in Military Decision Process," *Operations Research for Military Organizations*, 8: 155-184 (January 2019).
- The White House. *Interim National Security Strategic Guidance March 2021*. INSSG. Washington: The White House, March 2021.
- U.S. Air Force (USAF). *Air Force Doctrine Note 1-21 – Agile Combat Employment*. AFDN 1-21. Washington: Department of the Air Force, 1 December 2021a.
- U.S. Air Force (USAF). *Air Force Doctrine Publication 1 – The Air Force*. AFDP-1. Washington: Department of the Air Force, 10 March 2021b.
- U.S. Air Force (USAF). *Air Force Doctrine Publication 3-36 – Air Mobility Operations*. AFDP 3-36. Washington: Department of the Air Force, 28 June 2019.
- U.S. Air Force (USAF). *Air Mobility Planning Factors*. AFPAM 10-1403. Washington: Department of the Air Force, 24 October 2018.
- U.S. Air Force (USAF). *Department of Defense Fiscal Year (FY) 2022 Budget Estimates – Research, Development, Test & Evaluation, Air Force, Vol I*. Washington: Department of the Air Force, May 2021c.

U.S. Air Force (USAF). “Department of the Air Force Posture Statement.” Report to the Committees and Subcommittees of the United States Senate and the House of Representatives, 1st Session, 117th Congress, Washington DC. 7 May 2021d.

U.S. Air Force (USAF). *Future Air Force Vanguard Selection and Management Processes*. Washington: Department of the Air Force, December 2020.

U.S. Government Accountability Office (GAO). *DoD Can Better Leverage Existing Contested Mobility Studies and Improve Training*. Report to Congressional Committees. Washington: Government Accountability Office, 26 February 2021.

U.S. Government Accountability Office (GAO). *Weapon System Sustainment Aircraft Mission Capable Rates Generally Did Not Meet Goals and Cost of Sustaining Selected Weapon Systems Varied Widely*. Report to Congressional Requesters. Washington: Government Accountability Office, November 2020.

U.S. Transportation Command (USTRANSCOM). “Cooperative Research and Development Agreement between United States Transportation Command and Blue Origin LLC Space Transportation for the Department of Defense’s Joint Deployment and Distribution Environment.” Report to USTC/TCJA, HQ USTRANSCOM, Scott AFB IL. 17 December 2021.

U.S. Transportation Command (USTRANSCOM). “Final Report – U.S. Transportation Command – VOX Space, LLC Cooperative Research and Development Agreement 19-001 Researching Opportunities for Responsive Spacelift Serving Department of Defense Mobility Operations.” Report to USTC/TCJA, HQ USTRANSCOM, Scott AFB IL. 15 November 2019.

U.S. Transportation Command (USTRANSCOM). “Midterm Report – United States Transportation Command and Space Exploration Technologies dba SpaceX Cooperative Research and Development Agreement.” Report to USTC/TCJA, HQ USTRANSCOM, Scott AFB IL. 31 December 2020.

U.S. Transportation Command (USTRANSCOM). “Rocket cargo delivery gets big boost.” USTRANSCOM.mil. 7 June 2021. Retrieved on 2 December 2021.

Van Ovost, Jacqueline D. “Accelerating Change for Rapid Global Mobility – Delivering Joint Force Success in the High-End Fight,” *The Mitchell Forum*, 39: 1-10 (April 2021).

Vergun, David, “DoD Focuses on Aspirational Challenges in Future Warfighting.” Defense.gov. 26 July 2021. Retrieved on 3 September 2021.

Wampler, Richard L. and Margaret S. Salter. *The Military Decision-Making Process (MDMP): A Prototype Training Product*. Contract MDA903-92-D-0075. Alexandria VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 1998 (AD- A343154).

Wedley, William C. "Consistency prediction for incomplete AHP matrices," *Mathematical and Computer Modelling*, 17: 151-161 (March 1993).

Whitaker, Rozann. "Criticisms of the Analytic Hierarchy Process: Why they often make no sense," *Mathematical and Computer Modelling*, 46: 948-961 (October 2007).

Williams, Matt, "Musk hopes "Mechazilla" will catch and assemble the Starship and Super Heavy boosters for rapid reuse." Phys.org. 20 August 2021. Retrieved on 3 September 2021.

Vita

Major Kristofer “Fez” Fernandez was commissioned through the United States Air Force Reserve Officer Training Corps, graduating in 2009 with a degree in computer engineering from the New Jersey Institute of Technology. He later earned a master’s degree in aeronautical science from Embry Riddle Aeronautical University in 2017 and attended the Advanced Study of Air Mobility (ASAM), USAF Expeditionary Center, Joint Base McGuire-Dix-Lakehurst, New Jersey, in 2022 to complete a master’s degree in Operations Management from the Air Force Institute of Technology. Major Fernandez is a senior pilot with more than 3,400 flight hours and 130 combat sorties in the KC-10A Extender and C-5M Super Galaxy aircraft where he served as an evaluator pilot on both major weapon systems. Prior to ASAM, Major Fernandez was the Director of Operations at the 22d Airlift Squadron, Travis Air Force Base (AFB), CA, where he led day-to-day operations of 250 Airmen to operate \$4.8 billion in C-5M Super Galaxy strategic airlift assets including two of the USAF’s only Space Cargo Modified aircraft. Major Fernandez is an alumnus of the Defense Ventures Fellowship where he collaborated with some of the brightest minds in entrepreneurship, venture capital and cyber as well as DoD thought-leaders. His professional passion is to motivate mission-focused, cross-functional teams to solve problems with scalable innovation and to accelerate change by connecting intrapreneurs to dual-use technology and private capital for National Security.

REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.						
1. REPORT DATE (DD-MM-YYYY) 03/06/2022		2. REPORT TYPE Graduate Research Paper			3. DATES COVERED (From - To) July 2021 - June 2022	
4. TITLE AND SUBTITLE Decision Analysis with the Analytic Hierarchy Process as a Methodology to Develop a Model of Space Mobility Utility				5a. CONTRACT NUMBER		
				5b. GRANT NUMBER		
				5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Fernandez, Kristofer T., Major, USAF				5d. PROJECT NUMBER		
				5e. TASK NUMBER		
				5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way Wright-Patterson AFB OH 45433-7765				8. PERFORMING ORGANIZATION REPORT NUMBER AFIT-ENS-MS-22-J-041		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Colonel Jonathan N. Bland Air Mobility Command A4 400 Scott Drive Scott Air Force Base, IL 62225 jonathan.bland@us.af.mil				10. SPONSOR/MONITOR'S ACRONYM(S) AMC/A4		
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution Statement A. Approved for Public Release; Distribution Unlimited.						
13. SUPPLEMENTARY NOTES This work is declared a work of the U.S. Government and is not subject to copyright protection in the United States.						
14. ABSTRACT Great Power Competition highlights a requirement for a strategic lift capability with increased speed and range over current airlift platforms. Rapid advances in commercial rocket technology increasingly make point-to-point terrestrial spacelift, or Rocket Cargo, a leap-ahead capability available to the Combatant Commander. The Analytic Hierarchy Process was utilized as a methodology to develop a model based on decision analysis of air mobility focused logistics principles. The Model of Space Mobility Utility provides future strategists a foundational resource of fundamental Space Mobility Factors to consider when framing the utility of spacelift as a strategic mobility option for the United States.						
15. SUBJECT TERMS Model of Space Mobility Utility, Logistics, Rocket Cargo, Spacelift, Airlift, Decision Analysis						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE			Dr. Frank W. Ciarallo, AFIT/EN	
U	U	U	UU	154	19b. TELEPHONE NUMBER (Include area code) (937) 255-6565 x4702 frank.ciarallo@afit.edu	