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WINNING IN THE NEXT SPACE MARKET: PROSPECTS FOR FINANCIAL SUCCESS OF COMMERCIAL TRANSPORTATION SERVICES TO THE INTERNATIONAL SPACE STATION

A.C. Charania*

SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
ac@sei.aero

Dominic DePasquale†

SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
dominic.depasquale@sei.aero

ABSTRACT

NASA's Commercial Orbital Transportation Services (COTS) program is attempting to encourage emerging commercial companies to develop and demonstrate crew and cargo transportation services to the International Space Station (ISS). An independent assessment is presented of the COTS market utilizing the Nodal Economic Space Commerce (NESC) model, a dynamic Agent-Based Model (ABM) of supply and demand, including the effects of failure and government involvement. This study provides quantitative evidence that emerging space transportation companies can make a profit supporting the ISS and while providing substantial cost savings to the government.

NOMENCLATURE

COTS	Commercial Orbital Transportation Services
DDT&E	Design, Development, Testing, and Evaluation
ISS	International Space Station
LEO	Low Earth Orbit
NESC	Nodal Economic Space Commerce
NPV	Net present value

INTRODUCTION

Overview

A gap exists in the ability for the U.S. government to continuously operate the International Space Station (ISS) between retirement of the Space Shuttle in 2010 and initial availability of NASA's Crew Exploration Vehicle (CEV). Strains on the NASA budget due to lunar exploration priorities further hinder ISS activities even after the CEV is available. In response to this problem, NASA has expressed a willingness to purchase crew and cargo transportation services to the ISS from emerging commercial companies. Through the Commercial Orbital Transportation Services (COTS) program, NASA plans to make as much as one billion dollars available to companies for development and demonstration of vehicles capable of providing the needed services. The ultimate question about such space commercialization is the obvious: can firms achieve an acceptable financial return that will sustain their involvement in this market? SpaceWorks Engineering, Inc. (SEI) has undertaken a sophisticated economic modeling effort to address this question and to quantify the cost benefit to the

* - *Senior Futurist, Senior Member AIAA.*
† - *System Engineer, Member AIAA.*

U.S. government of using such commercial services to support the ISS.

An Emerging Market

The objectives of NASA's Commercial Orbital Transportation Services (COTS) project include:

1. Implement U.S. Space Exploration policy with an investment to stimulate commercial enterprises in space

2. Facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving reliable, cost effective access to Low-Earth-Orbit

3. Create a market environment in which commercial space transportation services are available to Government and private sector customers

NASA envisions multiple phases to the COTS program. Phase 1 will consist of development and demonstration of space transportation services to and from Low-Earth-Orbit (LEO) between 2006 and 2010. The Phase 1 capabilities (with fixed-price, pay-on-demonstration milestones) include the following:

A. External (Unpressurized) Cargo Delivery and Disposal
B. Internal (Pressurized) Cargo Delivery and Disposal
C. Internal (Pressurized) Cargo Delivery and Return
D. Crew Transport (optional for Phase I)

As of December 2006, two firms within the United States have been allocated NASA funding to demonstrate services in Phase 1 (contingent upon raising additional external investment and NASA exercising the capability D crew transport option): US$407M for Rocketplane Kistler (RpK) and US$586M to Space Exploration Technologies (SpaceX). Phase 2 will begin in 2010 with competitive bids for orbital transportation service (flexible services contracts for delivery orders) to support the ISS with crew and cargo.

PROCESS

Nodal Economic Commerce Model

Economic analysis of the ISS support market was performed using the SEI developed Nodal Economic Space Commerce (NESC) model. The authors have extensive experience applying these techniques to future space markets[1,2,3,4,5,6]. The NESC model is a dynamic space market simulation and financial engineering tool that uses Agent-Based Modeling (ABM) techniques to simulate the complex interactions between supply and demand (see Fig. 1). ABM has been used in the past to represent plants and animals in ecosystems, vehicles in traffic, and autonomous characters in animation and games[7,8,9,10]. A wide range of organizations including Macy's, Humana, and the U.S. Air Force Space Command have used and benefited from ABM simulations. Agent-based economic simulation is of higher fidelity than spreadsheet models, and better reflects reality by expressly modeling the individual actions and interactions of companies, their customers, and their competitors[11,12]. SEI's NESC model (written in the programming language JAVA) of transportation services to the ISS enables the simulation of price competition, new entrants to the market, reliability effects, and product differentiation (see Fig. 2). Various types of NESC model inputs (required economic return, vehicle capability, costs, etc.) define the worldview and behaviors of entities in the model. Each company "agent" autonomously decides its pricing strategy given market conditions and limited competitor information, together with its own unique costs and vehicle characteristics. Both expendable and reusable elements of a launch service are modeled as are development cost spreads and production learning effects. All vehicles in the model can fail according to their reliability, and when a commercial company's vehicle fails, there are additional costs to that company for both failure investigation and return-to-flight activities. NESC outputs the financial health of each company (cash flows, Net Present Value, market share, etc.) and can be used to explore various scenarios including supply vs. demand effects, customer influences, price changes over time, and product differentiation.

Model Inputs and Assumptions

The future space marketplace is simulated by modeling interactions between supply (orbital transportation service providers) and demand (the ISS). Definition of demand and supply factors is accomplished using data on ISS end-state (ISS configuration at Space Shuttle retirement) and public data on potential commercial transportation service providers. SEI has strived to develop reasonable proxies for firms that are representative of those that may participate in this market (see Table 1). Potential revenue from other markets such as sub-orbital and orbital tourism were not included in this analysis but have been modeled by SEI in other NESC simulations[1]. This study features two commercial companies, Firm A and Firm B, which compete with each other on the basis of price, reliability, and other factors for yearly government contracts. International Partners ESA and JAXA, operating the ATV and HTV vehicles respectively, each offer one flight per year in accordance with anticipated international agreements. Russian Soyuz and Progress vehicles are available in the event that commercial firms will not meet demand, but do not compete directly with those firms. Firm A operates a crew and a mixed (pressurized and unpressurized) cargo vehicle, while Firm B operates a crew, a pressurized, and an unpressurized cargo vehicle. Both firms' vehicles are reusable and have similar total capacity and turn-around-time. Firm A enjoys a reliability advantage and slightly lower development costs in comparison to Firm B, but Firm B has lower production costs and a longer lifetime for its vehicles.

The particular ISS configuration examined was that after 14 additional U.S. Space Shuttle flights (remaining as of late November 2006). The market period examined was from 2010 to 2017 (see Fig. 3). Approximately US$993 M of NASA COTS funding was applied to development costs of commercial companies, to account for both cargo and crew vehicle development. Overall assumptions for this study were made in late 2006, prior to some additional data being available. These estimates were based upon open source information. Additional, complementary markets were not integrated (orbital tourism, etc.) into the analysis. The probabilistic simulation included distributions on vehicle failures with mean values for output metrics such as price based upon 1,200 Monte Carlo simulations.

RESULTS AND CONCLUSIONS

Baseline Scenario

SpaceWorks Engineering, Inc. (SEI) has quantified the financial prospects of companies representative of those who want to support the International Space Station, as well as the potential savings obtained by the government by such outsourcing. This study is an independent assessment using publicly-available assumptions about demand, supply, and government involvement. The study examined the time period after retirement of the United States Space Shuttle in 2010, assuming NASA-funded Commercial Orbital Transportation Services (COTS) services type contracts. SEI has used its Nodal Economic Space Commerce (NESC) model to dynamically simulate this future market including vehicle failures.

Results from probabilistic simulation of the ISS support market spanning from 2010 to 2017 support several valuable conclusions (see Figures 4,5,6,7,8). Results indicate that given certain public knowledge about each firm's product and positioning, one of the two simulated firms can be financially successful in this market (mean Net Present Value of US$49.8 million) with some probability of success for the second firm. Additional results from the study indicate 95% of cargo would be delivered to the ISS using these suppliers with an expected mean vehicle failure rate for the COTS vehicles of 3.08 failures over the years examined. Given, this potential for failures, COTS companies should anticipate failure over the life of the program given the new products being offered and flight rates required. For the baseline scenario, when vehicle failures are considered probabilistically, a single firm (Firm A) is shown to be financially successful in terms of mean NPV after eight years of operation. There is still some probability that the second company achieves a positive NPV. The expected percentage of cargo delivered exceeds the level expected in a government-only transportation scenario. Mean prices for delivery of cargo (US$34,370 / kg) and crew (US$19.5 million / passenger) are below those expected for government-operated vehicles such as NASA's current Space Shuttle and future Orion Crew Exploration Vehicle (CEV). Between 2010 and 2017 commercial orbital transportation firms generate a total of over US$6.7 billion in revenue with the U.S. government saving over US$8 billion relative to the government-only transportation scenario.

Alternate Scenario

An alternate scenario was examined where certain inputs for both firms A and B were changed (see Fig. 10). Specifically, the time between flights for Firm A's vehicles is increased to 4 months and the reliabilities of Firm A and Firm B vehicles are swapped. This trade study was examined to show the flexibility of the NESC model framework to such scenario analysis. For this scenario both Firm A and Firm B are probabilistically likely to be financially successful, with Firm B achieving a greater mean Net Present Value (NPV) than Firm A (in addition to a positive NPV sooner than Firm A). This result is different from the baseline scenario and shows the potential tactics that could enable a more successful venture versus one's competitors.

CONCLUSIONS

Commercial companies can be financially successful delivering crew and cargo to the International Space Station (ISS). A diverse set of companies can be financially successful, even beating competitors if they position their product correctly in terms of capability, reliability, and price. Use of commercial providers for ISS support represents a potential win-win scenario for the United States Government and emerging commercial companies.

FUTURE WORK

Additional upgrades to NESC model include inclusion of better vehicle reliability into the simulation. This enhancement would include simulation of vehicle failures, return-to-operation schedule/cost impact, fleet replenishment, etc.

ACKNOWLEDGMENTS

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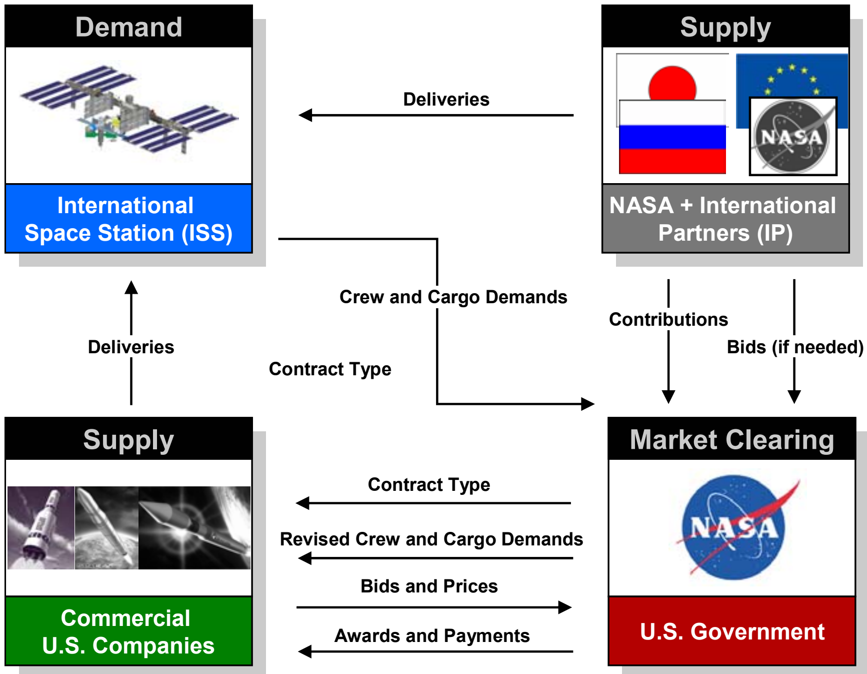


Figure 1. Market Interactions in SEI's Nodal Economic Space Commerce (NESC) Model

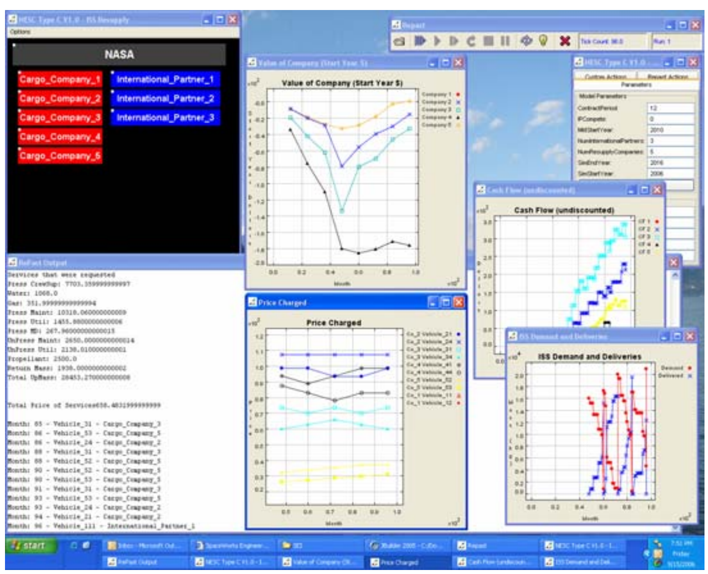


Figure 2. Implementation of NESC on a Windows® Personal Computer

Table 1. Inputs to NESC Model Defining Companies and Vehicles

	Characteristic		FIRM A Crew Vehicle	FIRM A Pressurized Cargo Vehicle	FIRM B Crew Vehicle	FIRM B Unpressurized Cargo Vehicle	FIRM B Pressurized Cargo Vehicle
Specs	DDT&E Start Year		2010	2006	2010	2006	2006
	IOC Year		2013	2010	2013	2010	2010
	Crew Capacity		7	0	5	0	0
	Reusable (1=Yes, 0=No)		1	1	1	1	1
	Time b/t Flights	(months)	2	2	2	2	2
Capacity	maxPress	(kg)	200	2500	50	0	2500
	maxUnPress	(kg)	600	600	0	3000	0
	maxWater	(kg)	0	300	0	250	200
	maxGas	(kg)	0	50	0	75	50
	maxPropellant	(kg)	0	0	0	0	0
	maxTotalCargo	(kg)	800	3100	50	3000	2500
	maxPressReturn	(kg)	200	2500	50	0	900
	maxUnpressReturn	(kg)	0	0	0	1400	0
Vehicle Costs	Development Cost	($M)	110	130	120	60	100
	Flight Test	($M)	135	120	130	50	60
	Production Cost	($M)	75	65	75	8	10
	LV Development Cost	($M)	0	100	0	80	120
	LV Cost	($M)	27	27	20	20	20
	Certification Cost	($M)	1	1	1	1	1
	ISS Configuration Cost	($M)	5	1	5	1	1
	Maintenance Cost	($M)	5	5	8	6	8
	Failure Cost	($M)	8	8	8	6	8
	Learning Curve Percent	(%)	90%	90%	90%	90%	90%
	Cost Skewing Profile		3	5	3	5	5
Ops Cost	Fixed Operating Cost	($M)	5	3	8	3	3
	Cost Per Flight	($M)	6	4	8	4	5
	Launch Site Fee	($M)	2	2	2	2	2
	Insurance	($M)	2	2	4	4	4
Reliability	Historical Flights		3	3	3	3	3
	Maximum Flights (if reusable)		10	10	30	30	30
	Design Reliability		0.97	0.97	0.95	0.95	0.95
	Down Time if Failure	(months)	12	6	12	6	6

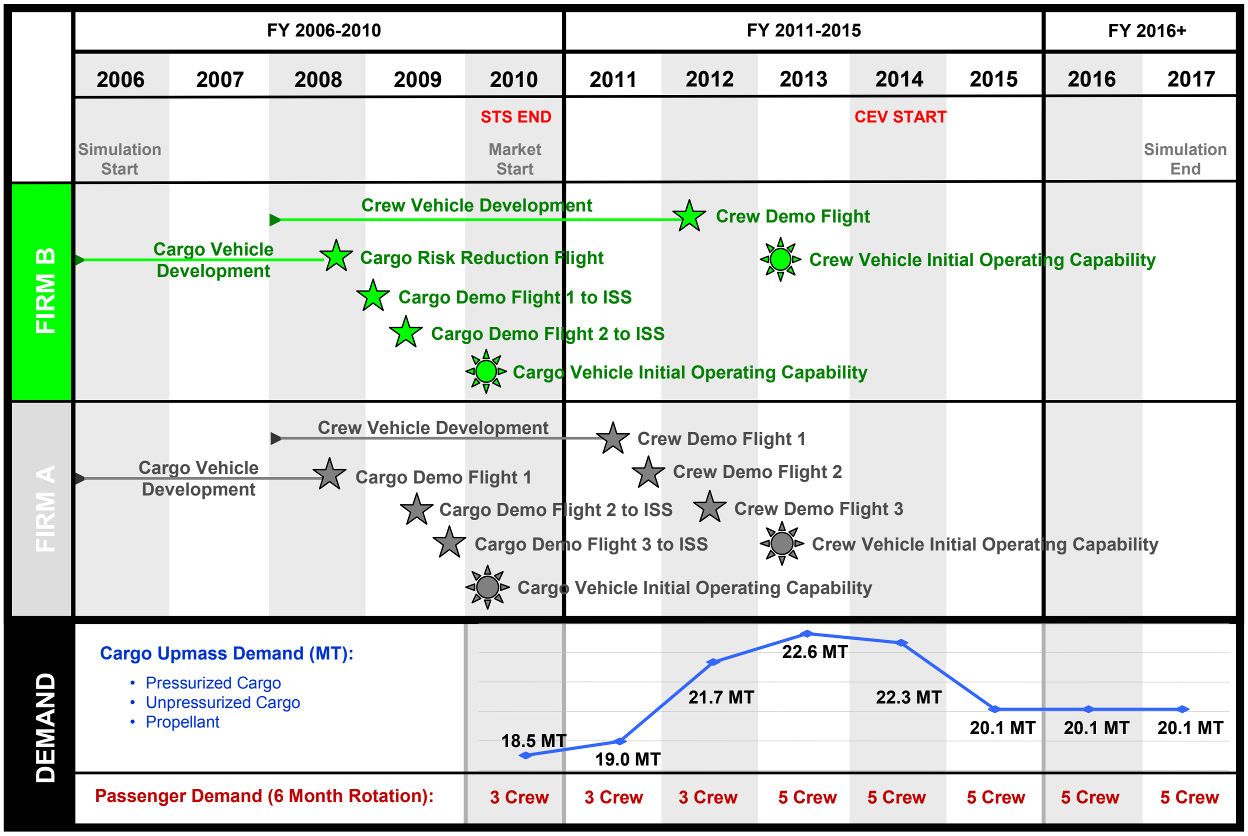
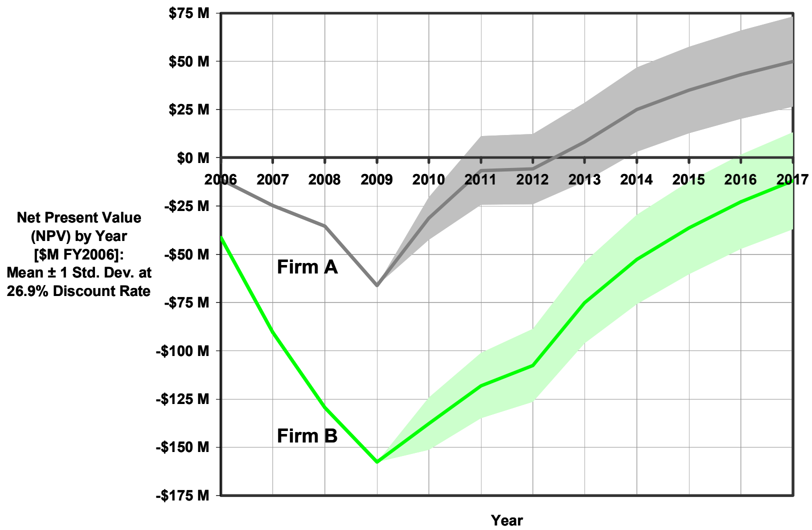
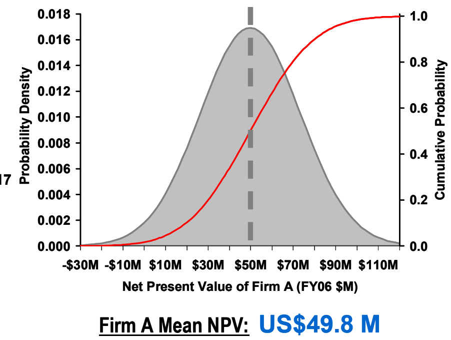


Figure 3. Company Development Schedule and Demand Summary





Note: Cash flows are discounted by Weighted Average Cost of Capital (WACC), a measure of the cost of capital which takes into account the debt and equity financing structure of the company. The WACC of 26.9% is based on a debt to equity ratio of 0.33, equity beta of comparable industries (Aerospace, Air Transport, E-Commerce), tax rate of 28%, average nominal interest rate of 7.5%, inflation of 2.1%, and risk-free rate of 6%.

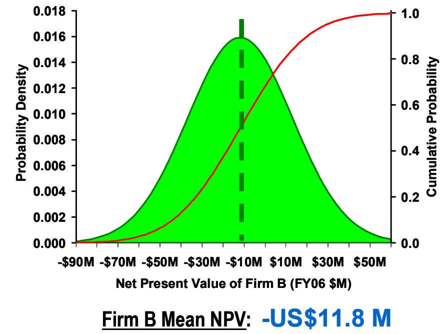


Figure 4. Financial Value of Supporting International Space Station (2010-2017): Baseline Scenario

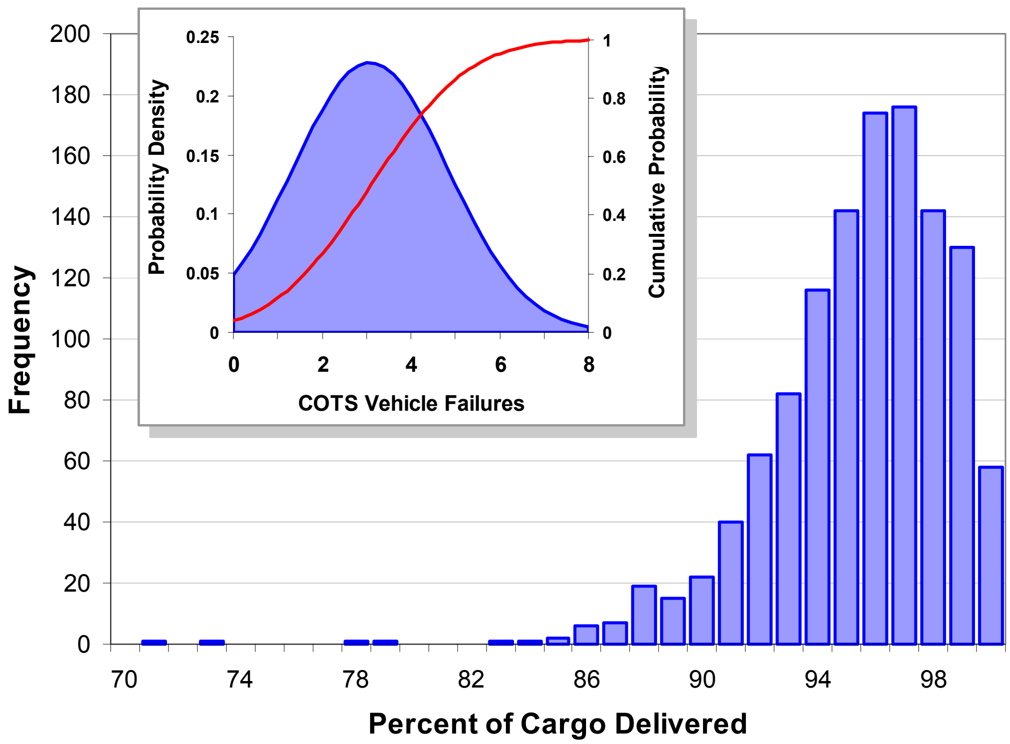


Figure 5. Percent of Demanded Cargo Able to be Delivered

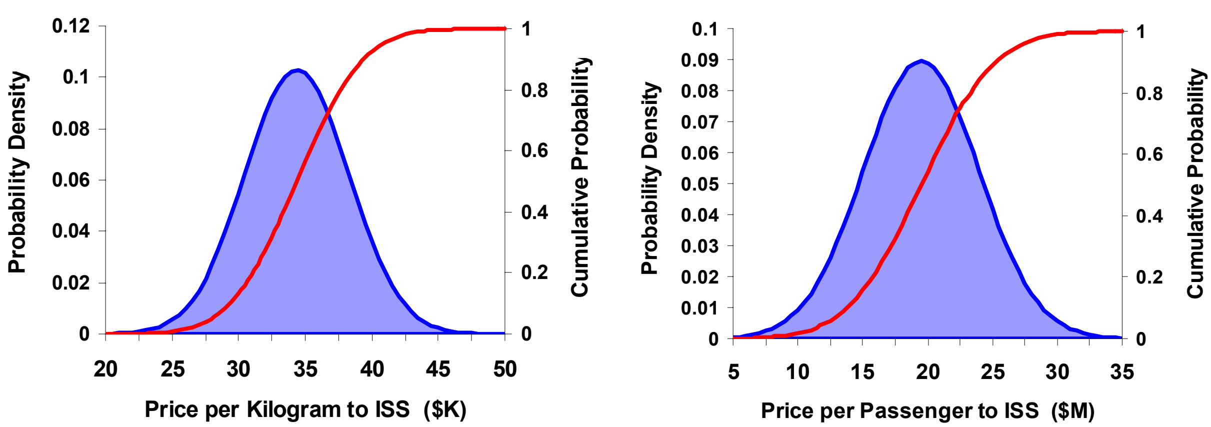


Figure 6. Prices for Delivery of Cargo and Crew to the International Space Station

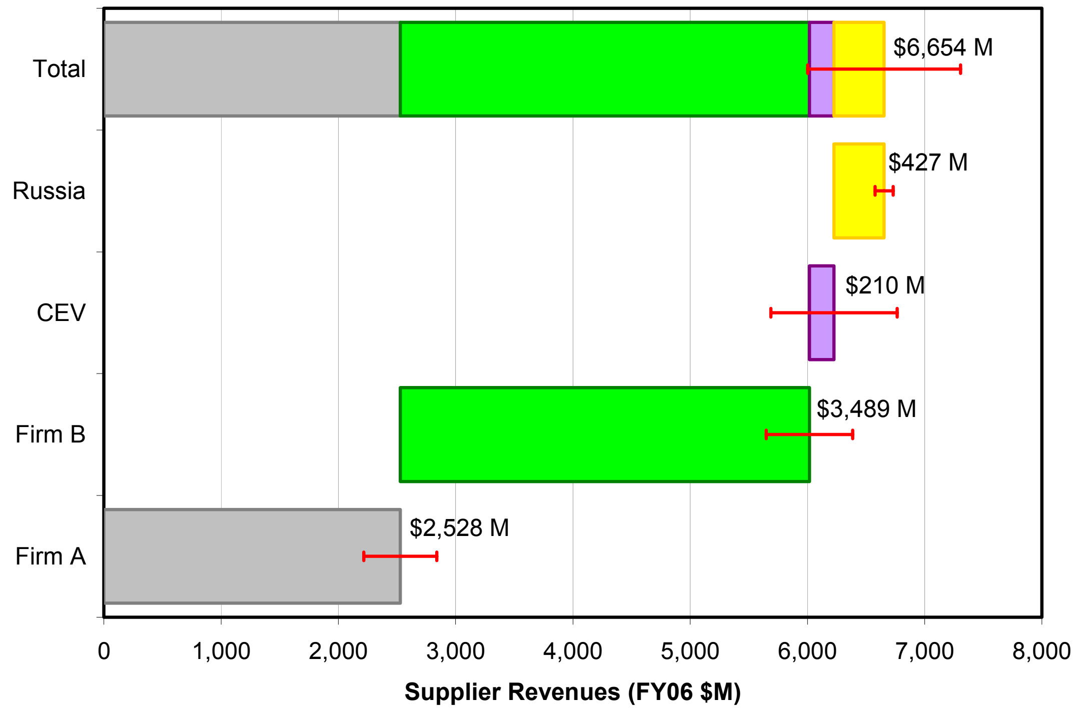


Figure 7. Cost to Supply International Space Station from 2010 to 2017

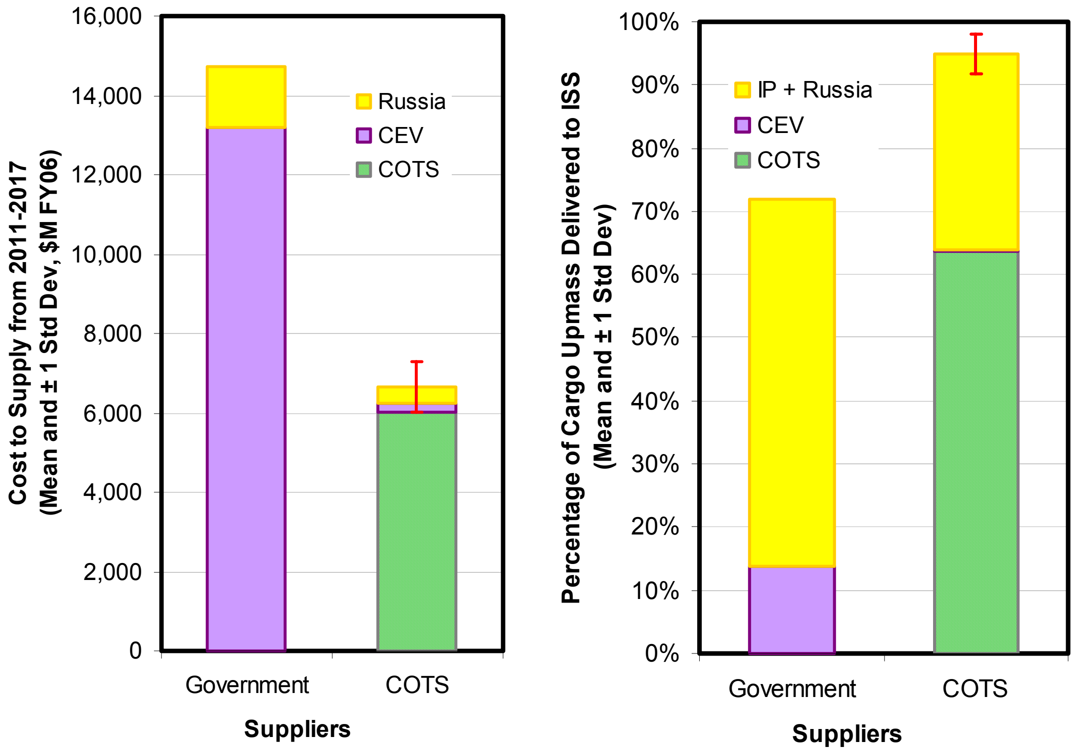


Figure 8. Potential Savings to U.S. Government by Commercial Providers

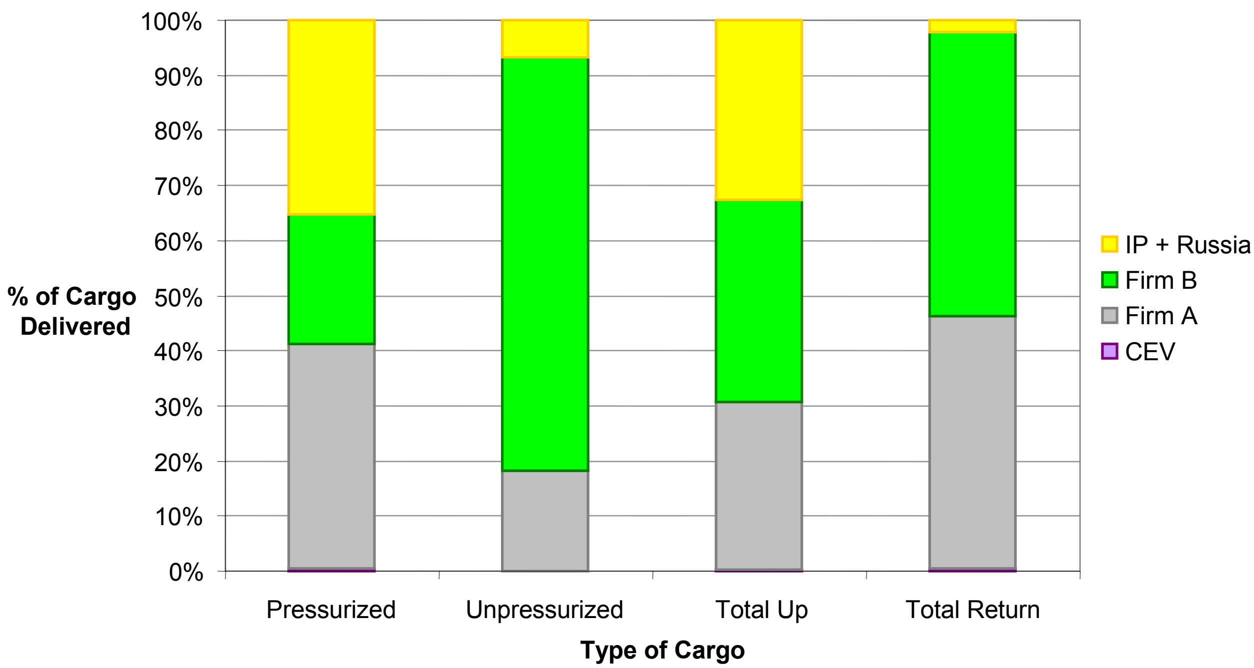
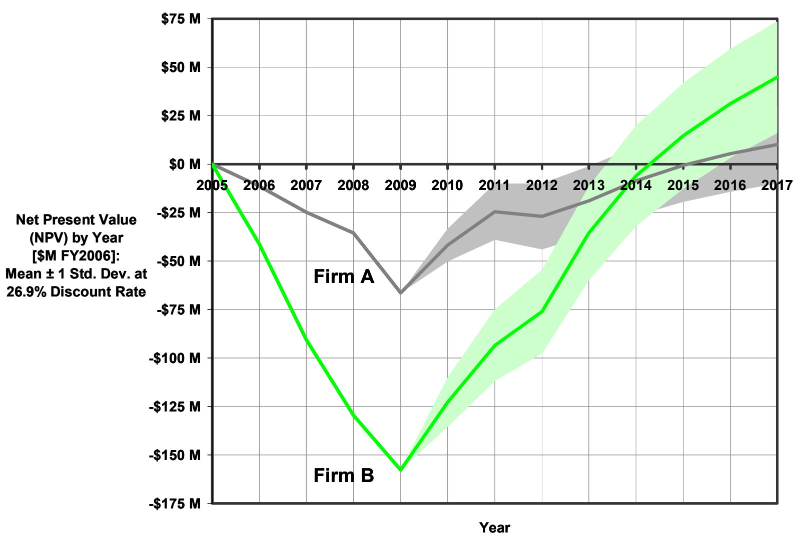


Figure 9. Distribution of Delivered Cargo Amongst Suppliers



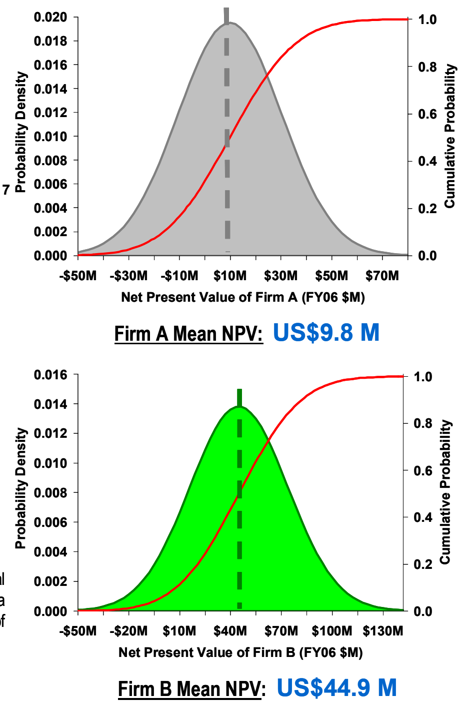


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Figure 10. Financial Value of Supporting International Space Station (2010-2017): Alternate Scenario