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AIMING TOWARDS VIABLE BUSINESS MODELS OF GLOBAL HYPERSONIC POINT-TO-POINT CARGO TRANSPORTATION

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ABSTRACT

Public and private organizations are currently determining how to develop future supersonic and hypersonic reusable vehicles. Many of these vehicles are being designed for very specific missions depending on the business models within which they are being funded. This paper builds upon previous analyses by the authors through an expanded investigation of the economics of a global point-to-point cargo transportation network that could be served by various hypersonic and supersonic vehicle concepts. The sample networks consist of various sets of global cities. The authors have developed several models to examine both the traffic times and fleet size requirements for to serve such a network. The GHoST [Global Hypersonic Shipping Time] calculator is used to compare input vehicle capabilities to the capabilities of existing package delivery services, and measure how much improvement is possible along these long-distance international routes. The second model, Descartes-PTP (Point-To-Point), uses Arena (a discrete event simulation software package) to simulate a network as a whole, determining for a given vehicle what fleet size and turnaround time are needed to support worldwide operations. These simulations are tied into the Cost and Business Analysis Module (CABAM) for financial, business-case evaluation of a particular combination of network traffic schedule and fleet size.

NOMENCLATURE

CABAM	Cost and Business Analysis Module
DES	Discrete Event Simulation
FF	FastForward
GHoST	Global Hypersonic Shipping Time
GMT	Greenwich Mean Time
HCV	Hypersonic Cruise Vehicle
SCV	Supersonic Concept Vehicle
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INTRODUCTION

The FastForward Study Group is a diverse, ad-hoc industry study group focused on common issues related to future global, high-speed point-to-point transportation (including passenger travel and fast package delivery)[1]. The team is broadly supported across the aerospace industry, with key members from flight system providers (both entrepreneurial and traditional aerospace hardware companies), future operators, government agencies, commercial aerospaceports, academic organizations, and specialist consultants. Members have backgrounds ranging from traditional aviation to space applications. The FastForward Study Group is focused on examining pre-competitive issues and questions key to understanding the technical and economic viability of future high-speed global transportation services based on either atmospheric or exo-atmospheric flight. These two emerging markets are related, and both share the goal of drastically reducing point-to-point travel times between distance points on the globe to a matter of hours.

Establishing a common understanding of the opportunities and challenges of these markets is critically important for all parties at an early stage (see Fig. 1). While specific implementation approaches and business strategies vary widely among the study team members, the goal of a safe, reliable, and affordable point-to-point commercial service is universally shared. Key FastForward study activities include market forecasting as a function of price and service class, identification of preferred locations and preferred characteristics of operational sites in the global network, establishment of payload, range, and flight speed requirements for the flight vehicles, identification of key technology prerequisites, and recognition of common regulatory and policy hurdles. The group also serves as an advocate for government policies and practices that would be favorable to engendering a strong U.S.-led market-driven business sector in ultra high-speed atmospheric and exo-atmospheric flight.

It is hoped such a forum can better define the suborbital market and explore preferred options for providing services (in a generic way -- i.e. flight frequencies, market size and price elasticity, preferred takeoff and landing destinations, required cargo capacity per flight, special handling requirements/limits). This type of information is a necessary pre-competitive part of everyone's future business plan. Collaborative subgroups of members are performing preliminary technical and economic analyses that will benefit all members. All members contribute reference documents, background material, and knowledge that is openly shared with the rest of the study group. Outside experts and guest speakers provide information to all group members (e.g. shippers, regulatory officials, etc.).

FASTFORWARD STUDY GROUP: RECENT ACTIVITIES

The FastForward Study Group was founded in 2008 and is managed by SpaceWorks Commercial of Atlanta, GA USA. For several years, there has been debate among those in the community as to the technical feasibility and financial viability of suborbital/orbital space tourism and high-speed global hypersonic point-to-point transportation. In August 2008, this interest led to the assembly of the FastForward (FF) study group, a pre-competitive collection of representatives from various stakeholder organizations that meets regularly to discuss the future possibilities of such a network. While the group has recently broadened its focus to take in passenger service, the first study efforts were targeted towards high-priority small package shipping.[1] The group's concrete products include technical papers and white papers on topics of PTP transportation for use by our members and the community at-large. Members meet regularly by telecon, supports a range of conference and panels, and use virtual collaboration tools to conduct business and exchange ideas. Currently, approximately 20 organizations are represented (by invitation) in the study group. Participation in the FastForward Study group is by invitation only. In order to have the most efficient discussion and dialogue with relevant parties, this approach has been taken. There is no fee to join and volunteer time is given by the study participants.

Participation in the study group includes access to the study's collaborative web site, email discussions, teleconferences, in-person meetings, etc. The team has set up a Google Group for discussion and file

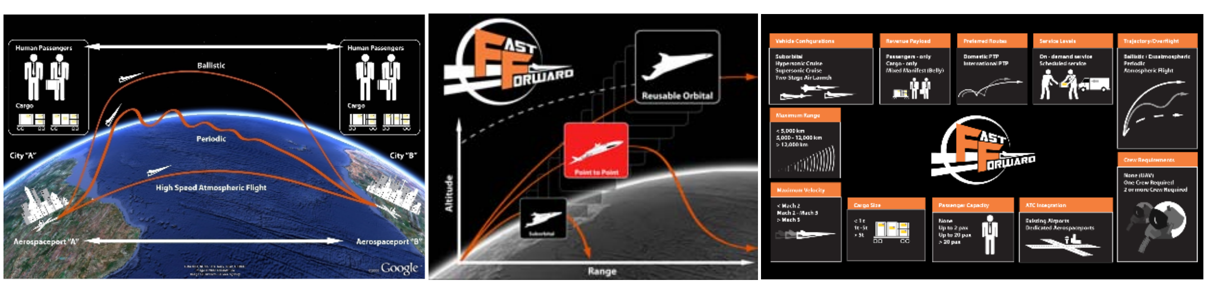

Figure 1. Point-To-Point (PTP), Evolutionary Path, and Options

sharing (by invitation only): http://groups.google.com/group/fastforwardstudy.

The group has held several teleconferences in 2008 and 2009 with both study group and external speakers. There has been one half-day face-to-face meeting on February 4, 2009 in Washington, D.C. (half-day workshop), just prior to the FAA's Commercial Space Transportation Conference. Another meeting is planned in 2009 during the International Symposium on Personal and Commercial Spaceflight (ISPCS) in Las Cruces, NM. Potential market approaches for high-speed global point-to-point travel are quite diverse, with several candidate options potentially leading to successful business models. These options includes various revenue payload options including: passengers (tourists, business travelers, VIPs), cargo (standard envelopes, freight, perishables), and mixed passengers/freight solutions (belly cargo). Another set of options includes the various destinations, such as: domestic service (e.g. east coast-west coast U.S.), international/global service (long distance transoceanic and transcontinental), and the potential to use a network of emerging international aerospaceports. Additionally, there are options for the type of service that would be offered, including: on-demand service (quick response flights taken when and where needed) and/or scheduled service (e.g. FedEx/UPS or airline type models). There are also a diverse set of preferred vehicle configurations represented by FastForward team members that could potentially work under some of the above mentioned models, but all must meet key requirements. These include the following:

- Economic Viability
  - What is the design market? Can it compete and make money?
- Technical Readiness
  - What are key technologies (propulsion, airframe, controls)
- Safety & Reliability
  - Can it achieve aircraft-like safety and reliability records?
- Environmental Impacts
  - What about SST downfalls: noise, land overflight, emissions?
- Regulatory & Legal
  - Can high-speed point-to-point overcome regulatory and legal hurdles: streamlined customs, liability, overflight of non-participatory countries, integration with ATC systems?

One can also begin to examine various city pair sets for such point-to-point services. Some of the FastForward study team members have been looking at potential city pairs defined in terms of three possible 'tiers' of cities in between which all possible routes would be flown. Tier 1, the base case, consisted of Los Angeles, New York, London, Cologne, Shanghai, Hong Kong, and Tokyo. The second tier added Mumbai, Dubai, and Sydney, and tier 3 added Buenos Aires, Sao Paulo, and Johannesburg. In all of these cases, routes are not flown between cities serving the same global region. For example, given the nature of existing regulations, a hypersonic New York – Los Angeles flight would be impossible. The other groupings without links to each other are London and Cologne; Shanghai, Hong Kong, and Tokyo; Mumbai and Dubai; and Buenos Aires and Sao Paulo. All other routes are potentially flows, subject to the constraints of the vehicle studied. The FastForward vehicle and these city groups, having already been selected, were used as the base case for some of the analyses members of the team have conducted. These city pairs are deemed to represent a good starting point for discussion within the Study Group.

Overall, there are several specific current areas of investigation for some of the members of the FastForward Study Group, including: an investigation of the difference between hypersonic and supersonic service, examination of market size, and identification of spaceport challenges[1,2,3].

RECENT MODELING EFFORTS

In order to determine whether the whole transportation network is a feasible idea, estimates had to be made of market potential. This required building models to help quantify how hypersonic service compared with available subsonic services, as well as aiding in the vehicle design process by defining what levels of performance were required to represent significant advantages over that service. While these models have been mentioned in previous work written by the FF group, they have been further developed over the last year to make them both more flexible and more informative, and the purpose of this paper is to explain them in greater detail[3]. A summary of some of these models is given below.

The Global Hypersonic Shipping Time (GHoST) Calculator is a spreadsheet model developed to enable easy analysis of the time advantages achievable by a high-speed vehicle compared to existing commercial package service on a given shipping network. GHoST is maintained at SEI, and is currently utilized in support of the FastForward study group's efforts to understand the market potential of this type of global hypersonic service. The layout of GHoST is dominated by a complete list of all theoretically possible routes between any two cities, with each route's data occupying fifty cells in a single row. The routes are grouped by the tiers of service and, in effect, each of the three tiers is being analyzed in parallel within the same model. The GHoST Calculator gives an in-depth picture of the routes achievable for a high-speed transportation network, and how the performance of those routes compares to existing commercial priority shipping options. A user is presented with useful summary graphs, and also has their attention drawn to key individual routes they can inspect to make intelligent decisions about their input parameters. The use of the delivery day as a metric is well-suited to the business model of the priority package shipment industry. In short, SEI's GHoST Calculator is an ideal model to incorporate into any study of next-generation high-speed cargo transportation networks.

Once a flight schedule has been established for a desired service network, manually or using GHoST, this schedule can be used to determine the number of vehicles needed to support the network. The complexities of the service network, particularly the fact it is spread across a complete range of time zones, require a model that can keep track of the movements of every individual plane, and track its availability to carry another shipment. Discrete Event Simulation (DES) is a methodology designed to handle exactly these sorts of problems[4]. A DES model was built to simulate a week's worth of high-speed package delivery flights over the global network defined by the FastForward study group.

Both the GHoST calculator and the DES model were developed for the specific purpose of supporting the FastForward study group's efforts to build a business case for a global hypersonic shipping network. Outputs from GHoST were used to justify various revenue-related assumptions driven by knowledge of the speed advantages of the service. The simulation was crucial in determining the number of vehicles that would have to be acquired, a significant driver of total program cost. As the FastForward group continues studying various scenarios, including passenger service, these models will continue to be relied upon for data.

Both models can also be used in conjunction with CABAM, the Cost and Business Analysis Module, a life cycle cost analysis tool maintained by SEI, originally developed in 2002 at Georgia Institute of Technology[5]. CABAM takes inputs from various disciplinary models and combines them with market assumptions and other financial factors to produce estimates of Net Present Value and other standard business metrics. CABAM is flexible enough to handle a wide range of launch vehicle programs, with varying levels of private vs. government funding, the possibility of learning curves, and it takes into account discount rates and debt-to-equity ratios, among other economic factors. The models presented here can help drive CABAM inputs, thereby improving the accuracy of the model as a whole.

HYPERSONIC VERSUS SUPERSONIC OPERATOR ANALYSIS

Using the above tools, specifically using the GHoST calculator, Arena DES model, and CABAM, a financial analysis was performed to compare notional hypersonic and supersonic service operators. Vehicle configurations were chosen, preliminary performance and cost analyses was performed, and financial analysis was conducted. Only cargo markets were examined here.

Hypersonic PTP Operator Overview

The authors recently performed an analysis of a notional hypersonic operator serving a global network of cities to deliver cargo[2,3]. The analysis was not meant to be a final and comprehensive design for an optimum business case. It was meant to be representative and a case study that can be used for comparison versus existing and other future systems. A summary of the results of the hypersonic system (from the previous analysis) is given. This vehicle is referred to as the Hypersonic Concept Vehicle (HCV).

As seen in Fig. 2, the authors previously developed a design for a notional remotely-piloted single-stage Point-To-Point (PTP) hypersonic waverider-type air/spacecraft that utilized a configuration periodic (skipping) trajectory[2]. This reference PTP HCV utilizes a unique rocket-based combined cycle

(RBCC) hypersonic propulsion system to achieve high-speed flight. Boost-phase propulsion would be provided by two LOX and hydrocarbon-fueled (JP-10) ejector-scramjet air-breathing engines. The required cutoff velocity was approximately Mach 18 - 20 for most of the baseline routes. Overall fuselage length is 24.6 m. Wingspan is 15.6 m. The vehicle would take off horizontally from a new airport/spaceport and land horizontally at the destination. The maximum flight range for this notional PTP hypersonic vehicle is approximately 12,000 km non-stop with an average flight speed of 4,700 km/h.

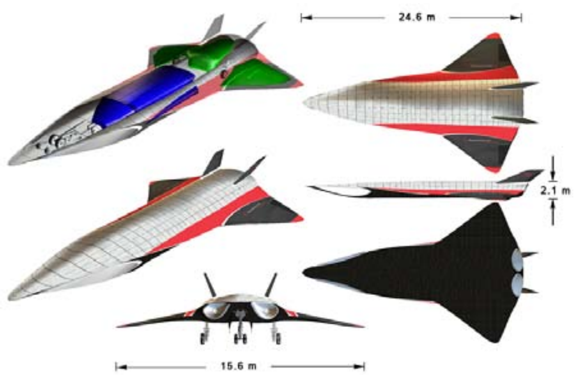

Figure 2. Reference Hypersonic HCV PTP Fast Package Delivery Concept[2]

The vehicle is *designed* to carry up to 1,000 kg (2,204 lb) of revenue payload, although not all flights will be full. The total gross mass of the vehicle at takeoff is 154,740 kg (342,900 lb). Turnaround time (time between scheduled flights) is estimated to be approximately 20 hours. IOC (Initial Operating Capability) is estimated to be 2020 with approximately 20 flight years with the input demand of 7,800 flights per year (30 flights per day x 5 days x 52 weeks).

As seen in Table 1, the total development cost for the system is estimated to be approximately $4.5 B. Acquiring the first unit will cost approximately $323 M, and the cost to develop and acquire the first vehicle is approximately $4.8 B (Note: these values in FY2008US$M). Facilities development is qualitatively estimated at $250 M each for seven global facilities. Direct recurring cost (with depot maintenance) is $0.323 M/flight (FY2008US$M). The minimum fleet size required for the mission scenario (5 days per week, 30 flights per business day, 52 weeks per year) is thirty-five (35) vehicle airframes (includes a five vehicle margin). The Weighted Average Cost of Capital (WACC) is estimated to be 15.82%. Assuming the average payload per flight is fixed at 460 kg per an initial market assessment, the price per kg is to achieve an Net Present Value (NPV) equal to 0 is estimated to be $1,694/kg (see Table 1)[1]. Figure 3 shows a parametric sweep of price per kg delivered to each destination versus payload. The initial economic design point in the study ($800/kg for 460kg) was a financially infeasible point. Thus the price was adjusted for this payload to achieve an NPV=0 condition (and thus the $1,694/kg value).

Table 1. HCV Financial Case A: NPV=0 @460kg/flight[2]†

Item	Value
WACC	15.82%
Payload	**460.0 kg**
Price	**$1,693.8/kg**
Net Present Value (NPV)	**$0.0 M**
DDT&E Cost	$4,458.5 M
Acquisition Cost	$10,377.9 M
Facilities Cost	$1,659.5 M
Recurring Cost	$29,266.0 M
Financing Cost	$9,663.7 M
Taxes	$19,809.2 M
Revenue	$121,546.1 M
Total Equity Investment	$9,392.3 M

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding

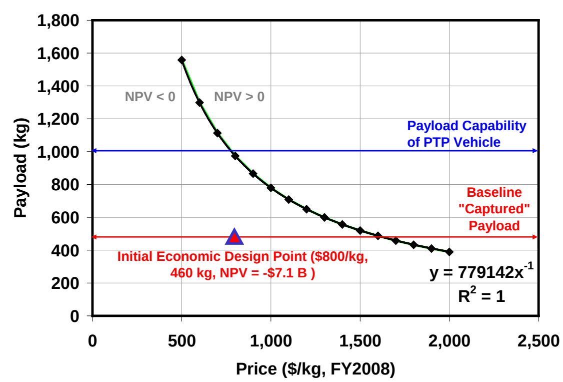

Figure 3. Combination of Price and Payload ("Captured Demand") for NPV =0 for Reference Hypersonic PTP Vehicle Concept[2]

Supersonic PTP Operator Overview

Given this analysis, the authors wondered how a slower and shorter range vehicle (a supersonic vehicle) would compare to this Mach 18-20 hypersonic vehicle. A notional supersonic operator was needed to be developed. The authors decided that unlike the previous analysis, that they would not perform a concept design of a notional PTP supersonic vehicle (like was done for the hypersonic case). Instead, the authors performed research to select a candidate supersonic vehicle from some that have already been designed to support the supersonic business jet market. These vehicles currently do not exist, but multiple organizations have over the last few years developed some concept design studies for such supersonic systems. The authors did not select a large, high-speed passenger vehicle such as the Concorde or concepts based upon High-Speed Civil Transport (HSCT) designs. Table 2 displays technical and cost characteristics for several potential near-term supersonic vehicle candidates (all data from public sources or from SpaceWorks Commercial assumptions). The concepts that were under consideration included the Quiet Supersonic Transport (QSST) by SAI, the Gulfstream Quite Supersonic Jet (referred to here as the "Whisperer") and the Aerion Supersonic Business Jet. The Gulfstream concept (hereinafter referred to as the Supersonic Concept Vehicle or SCV) was chosen as the supersonic business jet to use in comparison with the HCV.

Table 2. Potential Supersonic Business Jet Concepts

Value	SAI Quiet Supersonic Transport (QSST)	Gulfstream Quiet Supersonic Jet ("Whisperer")	Aerion Supersonic Business Jet (SBJ)
Flight Velocity	1,909 km/h	2,205 km/h	2,205 km/h
Range	7,800 km	7,408 km	8,890 km
Payload	1,143 kg	1,143 kg	1,143 kg
Development Cost	$1.4 B	$2.5 B	$2.5 B
Acquisition Cost	$80 M	$80 M	$80 M

Since the HCV described in the previous section was an all cargo vehicle, some assumptions were made to the convert the Gulfstream passenger vehicle into a cargo variant. The Whisperer cargo variant was developed by the taking the original concept and removing the passenger capability. Using an industry standard ratio of 10 passengers = 1 MT, and removing 12 passengers, the Breguet range equation yields a new range of 8,890 km. Vehicle costs were unchained.

Logistical Comparison

A comparative analysis was performed of these just described hypersonic (flight velocity: 4,700 km/h, range: 12,000 km) and supersonic (flight velocity: 2,205 km/h, range: 8,890 km) operational concepts. The purpose was to determine the capabilities and prices per kg that each service would need to charge. For this analysis, similar demand and city pair combinations were used as that used for the HCV analysis (see Fig. 4).

Figure 4. Selected City Pair Combinations

The first step was to use the GHoST calculator to find viable city pairs for the SCV and HCV. Tables 3 and 4 show the feasible city pair combinations for various tiers of cities in the network. These tables show how many routes from the origin city (to all other cities in the network, for that tier) that each concept can meet. The tables include multiple assumptions on city-pair logistics within the GhoST calculator[2]. It can be seen that given the reduction in range and speed for the SCV, it can only meet a subset of the HCV's city pairs (only a 1/3 of the Tier 1 cities for instance). This ratio starts increasing the more city pairs one adds, such that eventually the SCV can meet about 52% of the HCV's city pair combinations.

Table 3. Feasible City Pair Combinations for Supersonic Concept Vehicle (SCV)

	Origin City	Tier 1 Routes	Tier 2 Routes	Tier 3 Routes
Feasible Route Counts	Los Angeles	2	2	2
	New York	2	2	4
	London	2	4	4
	Cologne	2	4	5
	Shanghai	1	4	4
	Hong Kong	0	3	3
	Tokyo	1	4	4
	Mumbai	0	5	6
	Dubai	0	5	6
	Sydney	0	3	3
	Buenos Aires	0	0	2
	Sao Paulo	0	0	2
	Johannesburg	0	0	5
	Total	**10**	**36**	**50**

Table 4. Feasible City Pair Combinations for Hypersonic Concept Vehicle (HCV)

	Origin City	Tier 1 Routes	Tier 2 Routes	Tier 3 Routes
Feasible Route Counts	Los Angeles	5	5	7
	New York	4	5	7
	London	5	7	10
	Cologne	5	7	10
	Shanghai	4	7	8
	Hong Kong	3	6	7
	Tokyo	4	7	7
	Mumbai	0	6	7
	Dubai	0	6	7
	Sydney	0	4	6
	Buenos Aires	0	0	6
	Sao Paulo	0	0	5
	Johannesburg	0	0	9
	Total	**30**	**60**	**96**

Using the above inputs for the range and speed for the SCV and HCV, various delivery characteristics can be determined for these operators. The GHoST calculator includes delivery hours for fast services offered by UPS and FedEx (included as comparison). Fig. 5 and 6 show the average delivery days and hours for the two operational concepts.

Although the idea of delivery hours may be easy to understand, and while it is displayed as one form of comparison, it does not always make sense in this industry[3]. For example, if an existing service can deliver a package by 8 am on Wednesday, it doesn't generally make a real difference if a new service can deliver the package by 2 am. Despite being "6 hours faster," this won't have the package in the hands of the recipients any earlier. To explain this concept, the idea of a 'delivery day' was developed. Delivery days are based on the idea that the standard delivery paradigm consists of an afternoon drop off and a morning delivery. An 'overnight' service matching this pattern is labeled as 1.0 delivery days. If delivery cannot be guaranteed until midday, 0.1 delivery days are added. If it is not guaranteed until the close of business, 0.2 days are added. Likewise, if midday drop off is needed for morning delivery, that adds 0.1 delivery days. Both metrics are shown in Fig. 5 and 6.

It can be seen that both the SCV and HCV are better than existing services. The HCV is slightly better than SCV when comparing both delivery days and hours. As with the feasible combination in Tables 3 and 4, this ratio of improvement (HCV versus SCV) decreases over time. A larger improvement of HCV versus SCV is not seen because in city pairs there are non-fast delivery times (at each end) that are constant over a city pair (vehicle to customer door delivery time). In addition, improvement occurs (in terms of delivery days) when packages arrive before standard delivery times during the day. For instance, an HCV can deliver a package at 02:00 for a particular city pair, but that package will not go out until 08:00 (standard ground departure time for the day). Thus the SCV has time to meet the HCV "delivery" time. This can occur over multiple city pairs and thus, averaged over these combinations, the HCV may only provide a slight improvement versus the SCV.

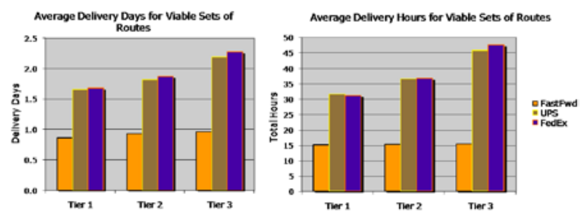

Figure 5. SCV: Average Delivery Characteristics Versus Current FedEx/UPS Service

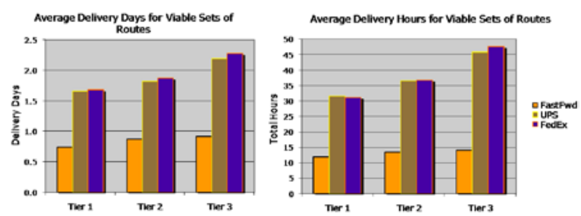

Figure 6. HCV: Average Delivery Characteristics Versus Current FedEx/UPS Service

Market Demand Assumptions

Before a financial analysis was performed, some previous assumptions of market demand as used in the original HCV analysis were modified (the original market capture assumption was revised, as seen from Table 5 to Table 6)[1]. The actual market sizing function itself used in the previous analysis was unchanged, but two parameters were changed, specifically the percentage of overall market served by our city-pairs and the total number of flights per day (10 versus 30, for Tier 1 city pairs, inclusion of all networks will lower market sizing further, favorably affecting the pricing strategy). Whereas the original analysis extrapolated from FedEx data, this updated analysis started from UPS data (deemed to be a better source since it was more recent). Given these assumptions, the new market demand per flight becomes 954 kg/flight (average over all city pairs).

Additionally, some financial analysis assumptions were revised (used in the CABAM model), this resulted in a lower WACC of 13.04% (lower WACC relative to the HCV). For modeling of the SCV, many similar operational and cost assumptions were utilized as those in the HCV analysis. There were some differences in these assumptions, specifically:

- Number of ground crew per SCV is 50 (ground crew determined by comparison to FedEx requirements for their Memphis mega-hub, and similar requirements for UPS)
- Number of facilities is 13 (for Tier 1 city pairs)
- Propellant loading of 22,700 kg of jet fuel (using prices for the week of 01 June 2009)
- Vehicle reliability is assumed similar to that of the Concorde
- Approximately 2,600 flights per year
- Payload capacity set to new market size

Table 5. Initial Calculation of Demand Per Flight for Fast PTP Cargo (extrapolation from FedEx data)[2]

Calculation Item	Value	Units	Comments
FedEx Average Daily International Package Volume	865,000	packages/day	Based on 2006 data
Divide by FedEx Market Share	21%	%	
Multiply by Percentage of Current Earliest AM Service Customers	5%	%	
Multiply by Percentage of Current Customers to Adopt New Service	80%	%	
Multiply by Percentage of Overall Market Served by Tier 1 Network	5%	%	
Multiply by Average Package Mass	0.60	kg/package	
Total Per Flight	460 / 1000	kg/flight	10 Flights Per Day, 460 – calculated, 1000 – qualitative estimate

Table 6. Initial Calculation of Demand Per Flight for Fast PTP Cargo (extrapolation from UPS/FedEX data)

Calculation Item	Value	Units	Comments
UPS Average Daily Delivery	15,500,000	packages/day	Source: UPS 2009 Form 10-K
UPS Approximate Internal Int'l Share	18.64%	%	Source: UPS 2009 Form 10-K
Divide by UPS Market Share	72%	%	Source: Wikinvest
Multiply by Percentage of Current Earliest AM Service Customers	5%	%	FedEx Assumptions
Multiply by Percentage of Current Customers to Adopt New Service	80%	%	FedEx Assumptions
Multiply by Percentage of Overall Market Served by Tier 1 Network	13%	%	FedEx Assumptions
Multiply by Average Package Mass	0.45	kg/package	FedEx Assumptions
Total Per Flight	954	kg/flight	10 Flights Per Day

Financial Analysis of Supersonic PTP Operators

Using the assumptions, financially modeling of the SCV using the CABAM model was performed. Tables 7, 8, and 9 show a few results from the CABAM analysis. Table 7 uses the new market demand value of 954 kg/flight and new WACC (13.04%) to determine the Net Present Value (NPV), in this case being positive (at more than US$2B). From this case A, a case B is analyzed where the payload is changed to obtain an NPV equal to zero, this occurs at a payload value of 616 kg. Fig. 7 illustrates the effect of such price changes on overall NPV. This yields a Case C (shown in Table 9) that takes the baseline payload value and changes the price to achieve an NPV equal to zero; in this case the breakeven price is $517/kg (a reduction of about 70% from the HCV breakeven price of $1,694/kg).

Table 7. SCV Financial Case A: NPV @954 kg/flight

Item	Value
WACC	13.04%
Payload	**954.0 kg**
Price	**$800/kg**
Net Present Value (NPV)	**$2,442.33 M**
Cost	$8,676.96 M
Revenue	$44,032.20 M
Total Equity Investment	$3,572.12 M

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding

Table 8. SCV Financial Case B:
NPV=0 @616 kg/flight

Item	Value
WACC	13.04%
Payload	**616.0 kg**
Price	**$800/kg**
Net Present Value (NPV)	**$0.0 M**
Cost	$8,676.96 M
Revenue	$28,443.25 M
Total Equity Investment	$3,572.12 M

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding

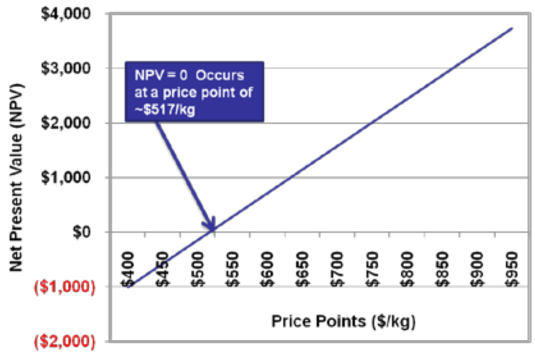

Figure 7. SCV: Parametric Sweep of Price

Table 9. SCV Financial Case C:
NPV=0 @954 kg/flight

Item	Value
WACC	13.04%
Payload	**954.0 kg**
Price	**$516.77/kg**
Net Present Value (NPV)	**$0.0 M**
Cost	$8,676.96 M
Revenue	$28,443.25 M
Total Equity Investment	$3,572.12 M

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding

Since the particular HCV price quoted just previous was for 460 kg/flight, there is an issue of inconsistent revenue payload demand being compared between the SCV and HCV. Going back to the original HCV analysis, there was a trade study using a 1,000 kg revenue payload (similar to the SCV payload)[2]. As seen in Table 10, for this case (Case D in the HCV analysis), the price of a similar payload demand for the HCV is about $780/kg. Thus the SCV's price (for a similar payload capability) is only 34% less than the HCV's price (price per kg of payload demanded).

Table 10. HCV Financial Case D:
NPV =0 @1000kg/flight[2]†

Item	Value
WACC	15.82%
Payload	**1,000.0 kg**
Price	**$779.1/kg**
Net Present Value (NPV)	**$0.0 M**
DDT&E Cost	$4,458.5 M
Acquisition Cost	$10,377.9 M
Facilities Cost	$1,659.5 M
Recurring Cost	$29,266.0 M
Financing Cost	$9,663.7 M
Taxes	$19,809.2 M
Revenue	$121,546.1 M
Total Equity Investment	$9,392.3 M

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding

A parametric sweep of payload for the SCV is shown in Fig. 8. As revenue payload starts getting lower (approximately less than 500 kg/flight), the price then substantially rises.

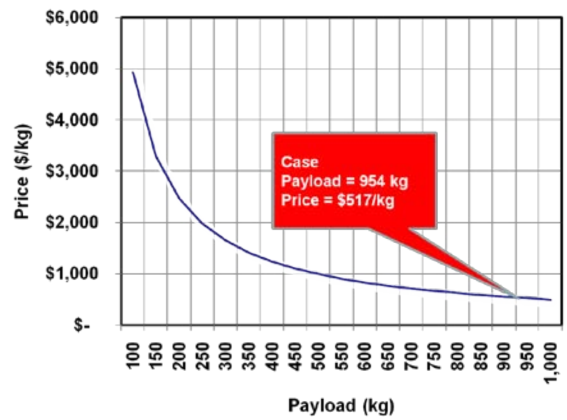

Figure 8. SCV: Parametric Sweep of NPV = 0 Range for Various Payload Quantity

<u>Selected City Pair Comparison</u>

Some more specific comparisons can be made between the SCV and HCV based operators. Fig. 9 and 10 show examples for two city specific city pairs (New York-Cologne and Los Angeles-Tokyo) for various service levels (FedEx, UPS, SCV, HCV, and Next Flight). The "Next Flight" category represents the price for putting the same package on the next available commercial subsonic flight (based upon commercially available prices). Both prices and delivery days are given for each delivery option.

As can be seen, delivery days experience improvement with supersonic transport (with similar outcomes as the hypersonic). The breakeven price point for supersonic is somewhat competitive to the hypersonic service, and significantly better than for courier service. Thus the value (time saved over marginal cost for a new service versus the same ratio for current service) is visible for multiple city pairs. Such comparative analysis is possible with the GHoST and CABAM models (coupled with data on current fast cargo transport services).

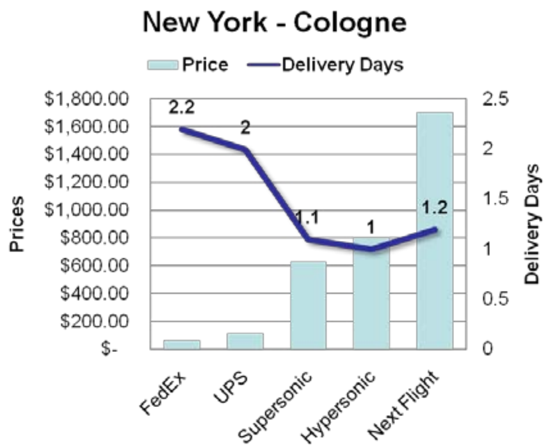

Figure 9. Price and Schedule Comparison for Various Delivery Services (including SCV and HCV): New York – Cologne City Pair

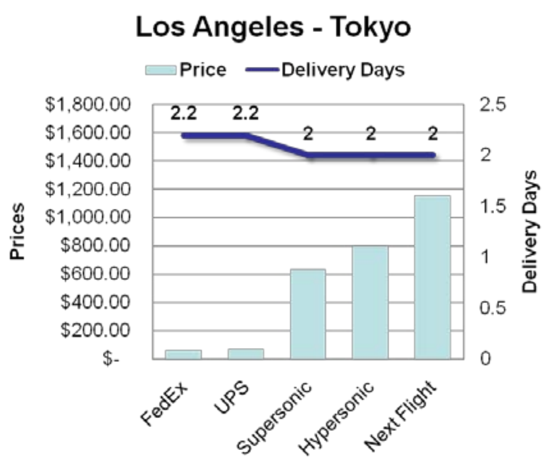

Figure 10. Price and Schedule Comparison for Various Delivery Services (including SCV and HCV): Los Angeles - Tokyo City Pair

Based upon the analysis described, a supersonic cargo delivery service is cheaper (in terms of overall cost and market price) than a hypersonic service, even though it can serve fewer city pairs. For the assumptions here, the SCV serves one-third of the Tier 1 cities, but for those cities has an average price that is 34% less than the HCV. Based upon analysis using the GHoST calculator, the HCV can serve more city pairs (in all Tiers) versus the SCV.

As shown in Table 11 (selected city pair delivery days for the HCV and SCV), for shorter range city-pairs faster may not be necessarily better (i.e. having a package ready for distribution by midnight vs. by 6am). In the case of city-pairs that can be served by either the HCV or SCV, the latter will most likely win contracts due to its cheaper price-point. There would be some city-to-city routes where the hypersonic vehicle would be a clear winner over the supersonic vehicle. This includes the London to New York route, due to an entire day's improvement in delivery service.

Table 11. Markets Served and Delivery Days: Various City Pairs

Start City	End City	Delivery Days: HCV	Delivery Days: SCV
Los Angeles	London	1.1	1.2
Los Angeles	Cologne	1.1	
Los Angeles	Shanghai	2	
Los Angeles	Hong Kong	2	
Los Angeles	Tokyo	2	2
New York	London	1	1.1
New York	Cologne	1	1.1
New York	Shanghai	1.2	
New York	Tokyo	1.2	
London	Los Angeles	0.3	0.3
London	New York	0.3	1.1
London	Shanghai	1.1	
London	Hong Kong	1.1	
London	Tokyo	1.1	
Cologne	Los Angeles	0.3	
Cologne	New York	0.3	0.3
Cologne	Shanghai	1	1.1
Cologne	Hong Kong	1	
Cologne	Tokyo	1.1	
Shanghai	Los Angeles	0.1	
Shanghai	New York	0.2	
Shanghai	London	1	
Shanghai	Cologne	0.3	0.3
Hong Kong	Los Angeles	0.1	
Hong Kong	London	0.3	
Hong Kong	Cologne	1	
Tokyo	Los Angeles	0.1	0.1
Tokyo	New York	0.2	
Tokyo	London	1	
Tokyo	Cologne	0.2	

SUMMARY

The FastForward Study Group continues to investigate issues with high-speed global point-to-point transportation. The group's overall intelligence on this subject is improving slightly with collaboration and data exchange within the group. Additional teleconferences and in person meetings are scheduled. Future technical papers and white papers will be released by the study group.

The lead study organization, SpaceWorks Commercial, continues to pursue its own analysis as part of the overall FastForward Study. This includes concept design, logistical analysis, and financial analysis. SpaceWorks Commercial has utilized and developed several tools to aid this analysis. Those tools, such as the GHoST calculator, Arena DES model, and CABAM can be used to determine overall financial viability. Previously SpaceWorks Commercial had performed a preliminary financial analysis of a hypersonic vehicle operator for a global point to point cargo delivery network. This has been updated with an analysis of a supersonic operator (based upon a supersonic business jet design). A comparative analysis was performed of these just described hypersonic (flight velocity: 4,700 km/h, range: 12,000 km) and supersonic (flight velocity: 2,205 km/h, range: 8,890 km) operational concepts. For the assumptions here, the supersonic service serves one-third of the Tier 1 cities, but for those cities has an average price that is 34% less than the hypersonic service. Expressed generally, the supersonic operator is more competitive on routes it supports. Future work on this specific comparative analysis could include exploring a tiered service level network (subsonic, supersonic, and hypersonic).

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