IAC-08-D2.4.5

IS THE WORLD READY FOR HIGH-SPEED INTERCONTINENTAL PACKAGE DELIVERY (YET)?

John R. Olds[*]
SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
john.olds@sei.aero

A.C. Charania[t]
SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
ac@sei.aero

Derek Webber[:t]
Spaceport Associates, United States of America (USA)
DWspace@aol.com

Jon G. Wallace[§]
SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
jon.wallace@sei.aero

Michael Kelly[**]
SpaceWorks Engineering, Inc. (SEI), United States of America (USA)
michael.kelly@sei.aero

ABSTRACT

This paper examines the prospects for a successful regularly-scheduled high-speed package delivery service for high-priority intercontinental cargo, notionally to be undertaken within the next decade or two. The topic is investigated from both technical/vehicle design and economics/business case points-of-view. Potential cargo include packages and priority items for which there might be a premium paid for speed, particularly if door-to-door service can be achieved fully one business day earlier than the fastest scheduled offerings currently available in the industry. The paper introduces a preliminary traffic model for a future business case, highlighting key routes and estimated daily volumes and price expected. Candidate flight vehicles and requisite technologies are discussed, with a particular point-to-point reference concept being presented to serve as the basis for non-recurring and recurring service cost estimates. The overall business case is then investigated, considering both the potential revenues and the likely costs or development and operation of the system. The challenges of the business case are summarized and are used to answer the question, "Is the World Ready for High-Speed Intercontinental Package Delivery (Yet)?"

[*] *-Chief Executive Officer, Associate Fellow AIAA*
[t] *-President, Commercial Division, Senior Member AIAA*
[:t] *-Washington DC Director, Senior Member AIAA*
[§] *-Senior Project Engineer, Engineering Division, Member AIAA*
[**] *-Operations Engineer, Engineering Division*

NOMENCLATURE

HCV	Hypersonic Cruise Vehicle
IRR	Internal Rate of Return
LEO	Low Earth Orbit
NPV	Net Present Value
PTP	Point–to-Point
RBCC	Rocket-Based Combined Cycle

INTRODUCTION

These are certainly exciting times for the aerospace industry. Significant advancements are being made on a variety of fronts including human exploration of space, unmanned aerial vehicles, robotic exploration, and hypersonic flight vehicles. Among the most captivating ideas is the emergence of a commercial space industry associated with private spaceflight. Several entrepreneurs, lead by Virgin Galactic's Sir Richard Branson, are engaged in the business of providing suborbital flight experiences to ordinary citizens [Ref. 1]. The market for these suborbital flights has been formally evaluated [Refs. 2, 3], and the business case for providing suborbital flights has been explored in some detail by the co-authors of this paper [Refs. 4, 5].

Invariably, the complementary market of using high-speed flight vehicles to provide fast-package delivery services is also suggested [Refs. 6 - 10]. However, with no rigorous economic assessment to support predictions of market viability, one must be left to speculate that "if you build it, they will come." Future investors will certainly require a more serious evaluation of this market segment before committing funds to support it.

We are therefore motivated on this ongoing research effort to try to introduce some rigorous analysis, even if initially somewhat limited in depth and scope, toward answering some fundamental questions related to prospects of a regularly-scheduled, high-speed intercontinental package delivery service. How big is this market? What types of customers would use this service? What premiums would they pay for additional speed? What are the most attractive routes? What are the requirements on a future flight vehicle that might service this market? Is there an economic business case to support investment?

Study Assumptions

As with any research effort, our conclusions will follow directly from the assumptions that we make at the study outset. These assumptions tend to frame our discussions and influence the scope of the effort. Future investigators might choose different study assumptions, so we present our major assumptions here for clarity and future comparison.

- We have limited our investigation to only the *express package* delivery segment of the market. These packages are typically time-critical and therefore would seem to benefit most significantly from reduced delivery times. Here, "packages" are assumed to be small envelopes and shipper-standard boxes in contrast to "freight" which is assumed to more massive time critical machinery, palletized parts, and specialized equipment. For most shipping service providers, "freight" is defined as items greater than 70 kg per box. While express packages can be any mass below that, the most typical express packages and envelopes would have a mass of 0.5 – 1 kg on average with a dimension of 45 cm x 30 cm x 10 cm or less.

- We consider only packages that travel by air and only on routes that involve *intercontinental* service. High-speed flight over heavily-populated continental land is currently problematic due to noise considerations. In addition, the longer transoceanic routes between continents are positioned to show the most benefit from a very fast air segment (compared to services built on the use of existing subsonic aircraft).

- In this paper, we consider only the market and business case for *regularly scheduled* service between selected city-pairs that serve as aggregating collection and distribution hubs for their regional areas. This business model is similar to the existing time-definite express cargo services offered by UPS, FedEx, DHL, European Air Transport (EAT), and others. We therefore have confined our study to business models that will easily integrate into one of these existing service providers or perhaps compete against them by offering faster point-to-point delivery times. An alternate business model has been suggested by some researchers -- the notion that there is a viable market for "on-demand" package delivery service using hypersonic or rocket vehicles (i.e. the concept that a flight vehicle would be waiting on standby for a single very high priority package to arrive) [Ref. 5]. Based on our initial evaluation of the very small size of this alternate market and the irregular schedules it would be subject to, we are currently removing it from our initial consideration.

- We assume that a limited number of facilities for the launch and landing of a new class of hypersonic vehicles would be created as needed on several continents to serve as distribution hubs for those regions (North America, South America, Europe, Asia, the Indian subcontinent, and Australia). Ideally, the new flight vehicles would be capable of integrating seamlessly into existing flight operations

at current cargo airports, but the regulatory, environmental impact, and operational considerations required to operate a new vehicle from existing airports are beyond the present scope of our research.

- We make the basic assumption that high-speed cargo delivery, for high value, time-critical cargos will precede a similar market for passengers due to its less stringent technology requirements and lower economic barriers against vehicle development. Therefore, we currently ignore any positive synergies between the potential cargo market and the eventual passenger market that might follow. As a result, the high-speed cargo business case is evaluated somewhat in isolation. Additional assumptions are stated throughout the remainder of the paper.

INTERNATIONAL EXPRESS AIR CARGO MARKET

As a point-of-departure, consider the existing international express air cargo market. In 2001, there were 31.7 million tons of scheduled air cargo delivered world wide [Ref. 11]. Top cargo destinations included the United States, continental Europe, the United Kingdom, China, and the rest of Asia (see Table 1)[Ref. 11].

Table 1. Top Air Cargo Exporters in 2001 [Ref. 11].

Rank	Country	Percentage of World Exports
1	US	12%
2	Germany	9%
3	UK	6%
4	Japan	6%
5	China	5%
6	France	5%
7	Italy	4%
8	Netherlands	3%

Key service providers in this market include FedEx, UPS, DHL, European Air Transport (EAT), and TNT Air Cargo. For the U.S. alone, airborne exports from U.S. cargo airports were valued at $251 B in 2001, over one-third of the export value across all modes (air, land, sea) [Ref. 12]. Additional data related to the existing express package market is available in the Appendix of this paper.

The air cargo market is divided into two segments based on size and mass of the individual objects. Air "freight" cargo consists of time critical parts, oversized objects and machinery, palletized cargo,

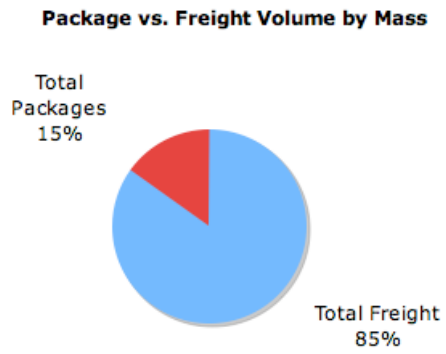

Figure 1. Segment Distribution by Mass [Ref. 13].

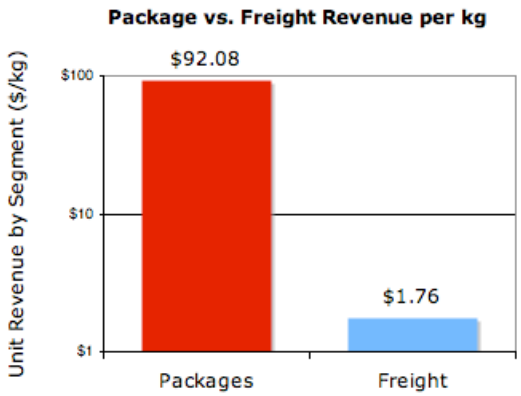

Figure 2. Segment Distribution by Revenue/kg [Ref. 14].

and similar large objects that ship by air. "Express package" cargo is comprised of smaller envelopes, airmailed packages, and small boxes (less than approximately 45 cm x 30 cm x 10 cm) having a typical mass of 0.5 – 1 kg. Typical express cargo includes direct-to-consumer packages, small electronics and electronic parts, original documents, pharmaceuticals, and similar time critical packages. In general, express packages are either unique or too expensive to produce or warehouse locally.

In the U.S. for 2007, air freight consisted of approximately 85% of cargo shipped *on the basis of mass* [Ref. 13]. However, *express packages generate a significantly higher proportion of revenue* relative to their mass. In 2006 for example, FedEx claimed revenues of $6.1 B from international express package service world wide, compared to only $1.2 B from international air freight for the same period. Also for 2006, FedEx's international express cargo service yielded an average revenue of $51 per package across all rate classes (approx $92 per kg). For the same period, the revenue generated from

international air freight was only $1.76 per kg. [Ref. 14] (see Figures 1 and 2).

Therefore, despite the larger size (in mass) of the air freight market, the smaller sizes, easier form factors, and higher unit revenue of the express package market make it a more attractive segment for the present study to consider. The authors' private conversations with current service providers indicate agreement with this decision. Air freight shippers may not, in a general sense, be as concerned with incremental speed improvements compared to express package shippers. Air freight shippers, for example, have adopted strategies to warehouse critical parts for regional distribution. Additional speed might reduce the need to hold inventory, but would likely not eliminate it. In contrast, more express packages are delivered to end-consumers who therefore see immediate benefits from faster service.

Time-Definite vs. Time-Critical Service

Air Cargo service providers offer two classes of express cargo delivery: time-definite (i.e. scheduled) and time-critical (i.e. on-demand, next flight available or other quick-response dedicated solutions). The former comprises the vast majority of the market segment. In 2007 for example, scheduled express cargo represented 77% of the express delivery market by mass [Ref. 12]. In this context, scheduled service consists of standard evening drop-off at an approved collection spot (say by 7 PM local time), pickup and transportation to the remote distribution center, and daily distribution to businesses and residences. In this model, trucks typically collect the daily packages and transport them to a local airport or aggregation center that then forwards the packages to a large cargo hub. A long-range aircraft is dispatched to a distant international hub where the packages are distributed out to local airports. Local delivery trucks are then stocked with the day's deliveries and leave the distribution center sometime in the early morning (say 8 AM local time). This is considered *time-definite* to the extent that the customer pays for guaranteed next morning delivery, next-afternoon delivery, second day delivery, etc. In private conversations with an industry service provider, this was indicated to be the preferred framework into which a next-generation fast-package delivery segment must conform.

In order to make an impact in the current time-definite express market, a new high-speed air vehicle must be able to improve the delivery service by a discrete jump. An aircraft/spacecraft that arrives at a distant location at 8:30 AM local time may miss the daily truck-based delivery schedule just as badly as one that arrives at 10:30 AM local time. However, an aircraft that arrives at its local airport at 5:30 AM enables its packages to be put on trucks for delivery that same day. It is therefore the focus of this paper to find delivery time requirements between key city-pairs that enable shippers to *realize a business day improvement* over the currently available shipping times (for example, next-day service to locations that currently only provide second-day service or even *same-day* service to intercontinental destinations that currently offer next-day service).

This strategy to align a future cargo delivery service with the processes and schedules of the existing shipping industry is a critical assumption that might be and perhaps should be challenged by future researchers. After all, it does seem technically feasible at least that a service provider might setup *on-demand* service to provide very high value package distribution (high value oil rig supplies or human organ transplants?) to key destinations and might provide his own trucking segments at both ends of the route. It is the authors' assumption however that this service is no more economically viable than say, placing the high value cargo on the next passenger plane out and picking it up at the destination airport by car. In fact, the major express carriers already offer 'next flight out' levels of service, but this sub-segment of the market is extremely small, extending to no more than a few hundred shipments per day worldwide. Given the small size of the time-critical market sub-segment and the existing competition as just described, it seems unlikely that this would result in a positive business case in the long run for a new flight capability developed solely on its basis. However, we encourage future researchers to test this hypothesis.

Selected Cities and Service Regions

Returning to our business model of 1) shipping express cargo packages, not air freight and 2) conforming to the model of scheduled delivery service to regular collections and daily distributions, we must further decide on the destinations to be served and the air segment flight time requirements. We started by identifying the top current cargo airports in the world based on annual mass emplaned. It is beyond the scope of our current study to characterize the challenges of integrating a new

rocket-type or hypersonic spaceplane into existing subsonic airport operations. So while these airports might not specifically be the locations or contain the infrastructure to support a new class of transporter, they are at least representative of the cities and regions that would need to be serviced. From the top cargo airports, we identified specifically those cities that are most likely to support or need long-range intercontinental cargo services, with advantages given to those cities that lie on coastal routes (to try to minimize overflight of populated areas). We further categorized the cities by tier to indicate whether they were a first, second, or third priority based on near-term cargo traffic. Table 2 shows those selected cargo cities. This information is shown graphically in Figure 3. Each city is assumed to serve a region around itself, typically within a few hours for both collection and distribution times by air or truck. For example, Los Angeles would be assumed to also serve many of the major markets in the western United States. In the Cologne/Frankfurt metropolitan area, Cologne was baselined because of the new UPS hub being developed there. Between the two large destinations of Tokyo and Seoul, we referenced our flight distances to Tokyo, although Seoul could easily be used as a replacement destination for that region.

Amongst the cities identified as Tier 1 cities, all seven were in the top 20 cargo originators and destinations in the world in 2006 [Ref. 15]. Tier 2 cities are considered emerging cities and regions that are poised to become large cargo destinations in the next 20 years. Tier 3 cities complete a logical global network. While large cargo hub airports such as Anchorage AL, Louisville KY, and Memphis TN are perennially listed amongst the top cargo airports in the world, they were not included in the list because their local regions do not naturally originate a large volume of cargo.

Table 2. Selected Cargo Cities.

Region	City	Tier
Western North America	Los Angeles	**1**
Eastern North America	New York	**1**
Western Europe	London	**1**
Central Europe	Cologne/Frankfurt	**1**
North China/Asia	Shanghai	**1**
South China/Asia	Hong Kong	**1**
Japan/Korea	Tokyo/Seoul	**1**
Middle East	Dubai	2
India/South Asia	Mumbai	2
Australia	Sydney	2
Brazil	Sao Paulo	3
South America	Buenos Aires	3
Southern Africa	Johannesburg	3

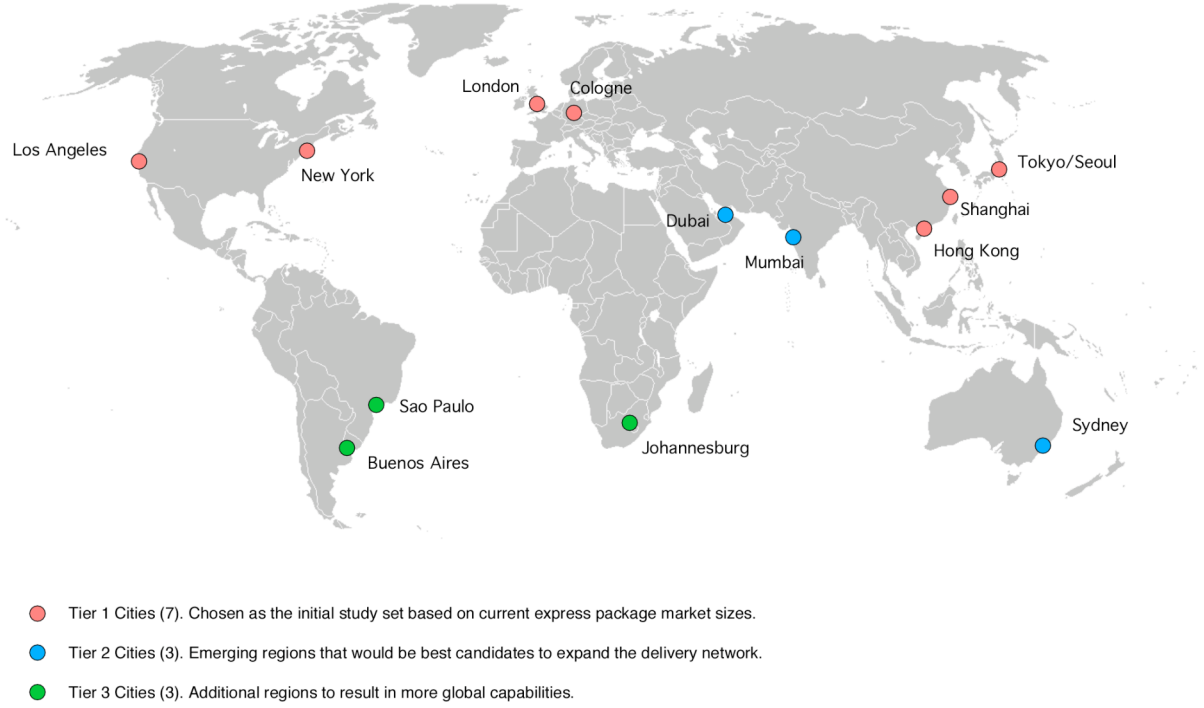

Figure 3. Selected Service Cities (by Tier).

Note that Sydney, Australia was strongly considered by the research team to be a member of the Tier 1 set, but was ultimately not included. Sydney is an interesting destination from a vehicle design point-of-view because it is a long range from the U.S. and Europe and therefore a very time-consuming leg. However, considering only existing cargo data, Sydney is neither currently a top destination nor originator for express air cargo. This is somewhat of a chicken-and-egg problem for Australia. Should true market data become available to support studies such as this, the authors would encourage market survey researchers to consider the price and volume characteristics of high-speed service to and from Australia.

Key Routes

We used our initial set of seven Tier 1 cities to develop a baseline route table. SpaceWorks Commercial created a spreadsheet-based tool to track city pairs, time zone differences, great circle ranges, collection and distribution times per city and pick up and delivery schedules per city. The GHoST (Global Hypersonic Space Transportation) calculator is shown in Figure 4. We eliminated short routes that would exist between cities on the same continent (less than 4,000 km, typically). In addition, for vehicle design reasons we selected a maximum range of 12,000 km between any two destinations. That had the effect to eliminate a single potential city pair (New York to Hong Kong). For the seven Tier 1 cities, the result was *30 daily flights* (counting New York to London and the reverse route of London to New York as two, for example).

Our goal is to understand the prospects for fast package delivery with an incremental improvement in delivery days compared to the fastest scheduled service offered between the same cities by providers such as FedEx and UPS. For example, UPS currently offers a scheduled service of three days between Los Angeles and Hong Kong. A package shipped using UPS' fastest World Wide Express+ service on Monday afternoon at 5:30 PM local time in LA would be delivered by 9:00 AM local time Thursday in Hong Kong. Our goal would be to enable a Wednesday option for this same route. Similarly, if the current fastest scheduled service between two of those cities was one day (e.g. London to New York),

SpaceWorks Engineering, Inc. (SEI)

GHoST Calculator

Version 2.2

Default Time Values (24 hr clock)		Start City Collection Time (hrs)		End City Dist. Time (hrs)	
Start City Time Value	1700	Cologne	3	Cologne	3
End City Time Value	800	London	4	London	4
		Los Angeles	5	Los Angeles	5
		New York	4	New York	4
		Shanghai	3	Shanghai	3
		Hong Kong	3	Hong Kong	3
		Tokyo	3	Tokyo	3

Cologne, London, LosAngeles, New York - Forward 1 hour

Start City	End City	Start City Time Value	End City Time Value (same day)	Great Circle Distance (km)	Start City Collection Time (hours)	End City Distribution Time (hours)	Time Zone difference (positive if destination is ahead)	Travel Time 1 day	Travel Time Target day	Travel 1 Speed (km/h)	Travel Speed for Target Day (km/h)	Target Delivery Day (relative to origin)
Cologne	Hong Kong	1700	800	9345	3	3	6	3	3	3115	3115	1
Cologne	Tokyo	1700	800	9359	3	3	7	2	2	4680	4680	1
Cologne	Shanghai	1700	800	8880	3	3	6	3	3	2960	2960	1
Cologne	New York	1200	1700	6069	3	4	-6	28	4	217	1517	0
Cologne	LosAngeles	1200	1700	9177	3	5	-9	30	6	306	1530	0
Hong Kong	London	1200	1700	9740	3	4	-7	29	5	336	1948	0
Hong Kong	Cologne	1700	800	9345	3	3	-6	15	15	623	623	1
Hong Kong	LosAngeles	1700	1700	11640	3	5	-15	31	7	375	1663	0
London	Hong Kong	1700	1200	9740	4	3	7	5	5	1948	1948	1
London	Tokyo	1700	1200	9585	4	3	8	4	4	2396	2396	1
London	Shanghai	1700	1200	9216	4	3	7	5	5	1843	1843	1
London	New York	1200	1700	5585	4	4	-5	26	2	215	2793	0
London	LosAngeles	1200	1700	8781	4	5	-8	28	4	314	2195	0
LosAngeles	Hong Kong	1700	800	11640	5	3	15	-8	16	0	728	2
LosAngeles	Tokyo	1500	1700	8815	5	3	16	2	2	4408	4408	1
LosAngeles	Shanghai	1700	800	10440	5	3	15	-8	16	0	653	2
LosAngeles	London	1700	1500	8781	5	4	8	5	5	1756	1756	1
LosAngeles	Cologne	1700	1500	9177	5	3	9	5	5	1835	1835	1
New York	Tokyo	1700	1700	10878	4	3	13	4	4	2720	2720	1
New York	Shanghai	1700	800	11888	4	3	12	-4	20	0	594	2
New York	London	1700	800	5585	4	4	5	2	2	2793	2793	1
New York	Cologne	1700	800	6069	4	3	6	2	2	3035	3035	1
Shanghai	London	1700	800	9216	3	4	-7	15	15	614	614	1
Shanghai	Cologne	1700	800	8880	3	3	-6	15	15	592	592	1
Shanghai	LosAngeles	1700	1500	10440	3	5	-15	29	5	360	2088	0
Shanghai	New York	1700	1700	11888	3	4	-12	29	5	410	2378	0
Tokyo	Cologne	1700	800	9359	3	3	-7	16	16	585	585	1
Tokyo	London	1700	800	9585	3	4	-8	16	16	599	599	1
Tokyo	New York	1700	1500	10878	3	4	-13	28	4	389	2720	0
Tokyo	LosAngeles	1700	1200	8815	3	5	-16	27	3	326	2938	0

Figure 4. SpaceWorks Commercial's GHoST Calculator for Baseline Set of Seven Cities.

we defined a schedule that could perform this delivery in the same day (relative to the shipper's departure day).

We entered representative collection and distribution times for each city into the GHoST calculator to represent typical times to collect packages at the drop point within the city's service region (e.g. 5 hours for Los Angeles for the cities it also serves) and a similar time to distribute packages from a regional airport out to the daily distribution centers in the region it serves (e.g. 3 hours for Hong Kong). Recall that the business model is to collect packages late in the afternoon at a drop location and have them at the regional distribution center in time to be loaded onto the daily trucks that will deliver them throughout the city. In most cases, we prefer a collection time near the close of a business day and delivery at the start of the local business day at the destination. Where possible, we assume a 5:00 PM pickup time and an 8:00 AM start time for distribution. However, some routes required adjustments to the basic schedule in order to meet our other goal of being one day incrementally faster than the fastest scheduled service offered by FedEx or UPS. Those adjustments are highlighted in blue in Figure 4. This data, along with the great circle range and time zone data for each route, enables us to calculate a required average flight velocity of the high-speed air segment that joins the two cities.

We found that the pacing non-stop range in our route table was about 11,900 km found between New York and Shanghai. Los Angeles to Hong Kong has a slightly lower, but similar range requirement. Our going-in position is that the new flight vehicle would be fast, capable of averaging hypersonic speeds. In general, routes from east to west *in terms of time zone differences* were easily accomplished with next day service, and with some adjustments in pickup and delivery times, even same day service was possible. Note that the actual flight direction is not important here. For example, Shanghai to Los Angeles would depart Shanghai in a northeasterly direction along a great circle, but gains a 15 time zone advantage because LA is west of Shanghai in terms of time zones.

Routes that travel west to east *in terms of time zone differences* present a more difficult challenge for this model. Because the destination is farther into the next day at the time of departure, there is effectively less travel time to reach the destination before its local trucks leave their respective distribution centers for the day's deliveries. If the average flight speed is high enough (say, above Mach 4 or 5), then next day delivery is still possible for destinations that are up to 6 – 7 time zones ahead of the departure location (New York to London overnight, for example). With delayed delivery or earlier collection options, then time zone differences up to 8 – 9 time zones become feasible (London to Hong Kong, for example). Beyond that, deliveries would have to drop back to second business day, rather than next business day. An express package leaving Los Angeles for Hong Kong on Monday afternoon would not be delivered until Wednesday morning Hong Kong time. In this extreme case, it is already well into Hong Kong's Tuesday early morning at the time the package is even picked up at the drop-off location in LA's service region. Allowing for collection and distribution times makes a Tuesday morning delivery impossible. Wednesday is the best option for this route. Note that this schedule is still one day faster than current scheduled services offered by FedEx and UPS per our baseline philosophy.

So, for the baseline set of seven city pairs, the following requirements on the vehicle emerge. The flight vehicle should have a minimum non-stop flight range of 12,000 km (about 6,400 nmi). The average flight speed, set by the most difficult west-to-east routes based on time zone, must be at least 4,700 km/h (roughly Mach 4.5 or greater depending on flight altitude). There are 30 daily flights required between the Tier 1 city pairs.

As an excursion, we considered the number of daily flights that would be required to service the Tier 1 *and* the Tier 2 cities in Table 2. There would be 64 flights per day to service this network (still assuming short routes under 4,000 km and long routes over 12,000 km would not be served by this class of flight vehicle). If the Tier 3 cities were also added to the network, then there would be 100 daily flights in the network.

If the flight vehicle were capable of almost antipodal range (half of the circumference of the Earth, approximately 20,000 km) then it would of course be capable of reaching any destination city from any starting city. This would naturally increase the number of available routes in the network. However, given the difficulty of fielding a high-speed flight vehicle with this range, we have limited our current study to routes under 12,000 km. Future researchers are encouraged address this limitation.

MARKET ASSESSMENT

Key aspects of the economic assessment of this prospective business venture include 1) the price premium that customers are willing to pay for the faster service, and 2) the volume of packages that might be shipped under this service. We have attempted to develop a reasonable estimate for these values in order to evaluate the potential revenue of the future business. As a word of caution, the authors have been warned by veterans of the shipping industry not to over simplify what is a very complex express cargo market. In private interviews, shipping executives were cautious to predict what value customers might place on speed. Certainly faster service would be welcomed by most, but at what premium for which routes? In an ideal case, we would commission market research to better answer this question, but resource limitations necessitate that we make informed estimates at this point in the study.

The Appendix to this paper contains a collection of background material on existing air freight services, with an associated set of references. It is instructive to see how far one can go in estimating the key parameters of a point-to-point hypersonic cargo delivery service merely from desk research of the existing service provisions, and for this purpose data in the Appendix has been used. Ultimately, however, it is not possible to derive a reliable centerline estimate of point-to-point cargo demand forecasts for a hypersonic cargo delivery service *without conducting some statistically valid market research*, and this has not been possible for this preliminary investigation. Nevertheless, we can make some progress, as demonstrated by the following steps.

By reference to Section 7 of the Appendix, it is clear that, at least regarding the FedEx Express segment (representing approximately 21% of the total, see Section 2.1 of the Appendix), the International Priority Package Service provides the most significant part of the international air cargo delivery revenue total as previously discussed. We therefore have focused on this segment, with its $6.1 B annual revenue, its 0.18 million kg (0.4 Mlbs) per day of traffic, and its $51 average price per package. From this data, we can first calculate that there are on average 120 million International Priority Packages delivered by FedEx per year. Secondly, we can compute the average package size, which turns out to be roughly 0.6 kg on average.

Since we know that the average package mass for existing express delivery business is near 0.6 kg, so we will only consider the data for that size package. The authors have collected example costs at this package size for several routes and tiers of service for two different international package shippers from online public sources as of July 2008. A subset of this data is given in Table 3.

Table 3. Example Express Package Prices (0.6 kg package, online sources circa 07/2008).

Service	Route	Price
FedEx Int'l Priority (10:30 AM delivery)	NYC - Brussels	$53
FedEx Int'l First (8:30 AM delivery)	NYC - Brussels	$98
FedEx Int'l Next Flight (next pax jet)	NYC - Brussels	$365
FedEx Int'l Priority (10:30 AM delivery)	LA - Tokyo	$52
FedEx Int'l Next Flight (next pax jet)	LA - Tokyo	$476
UPS Worldwide Expedited (typ. one day deferred)	NYC - Cologne	$104
UPS Worldwide Saver (end of day delivery)	NYC - Cologne	$110
UPS Worldwide Express (10:30 AM delivery)	NYC - Cologne	$114
UPS World Wide Express+ (9:00 AM delivery)	NYC - Cologne	$168

For the FedEx Express data shown in the table, FedEx International Next Flight in an on-demand (not scheduled) service, typically utilizing passenger jets for packages. FedEx International First is the fastest scheduled offering and FedEx International Priority is typically a mid-morning service. FedEx International First is only available on selected routes.

For the UPS Worldwide Saver, Express, and Express+ data shown in the table, the typical delivery schedule is two days from New York City to Cologne, Germany. UPS Worldwide Express+ is the fastest scheduled UPS offering, typically guaranteeing early morning delivery at the destination using a dedicated set of local delivery trucks and drivers. It is only available for selected destinations. UPS Worldwide Express is a mid-morning service, and UPS Worldwide Saver is a late afternoon service. UPS Worldwide Expedited service is a slower, in this case three-day, service.

This data is instructional, but not necessarily definitive. We do note the relatively modest premium increases from three-day to two-day service, and from afternoon delivery to mid-morning delivery.

However, there is clearly a sharp increase in premium for early morning service (perhaps a 50% - 100% premium relative to mid-morning service) and an even larger premium for the custom next flight out service offered by FedEx (perhaps a 10X premium relative to mid-morning service). These latter two categories are aimed at the very high priority customers that we would hope to serve with an ultra - fast package capability.

Thus, it would suggest that, at least for preliminary studies, a possible range for pricing of a high-speed hypersonic cargo delivery service offering a one day incremental improvement in schedule delivery time might be from $400/kg to $1,050/kg. The lower limit established by a 50% premium over the early morning service from NYC to Cologne and the upper limit by the existing next-flight out service from LA to Tokyo (both normalized to a 1 kg unit mass). Alternately, one might hypothesize that a 10X premium over FedEx Express' average package revenue price of $112/kg ($51/lb), that is $1,100/kg, might also be a reasonable upper estimate of the market given the established premium for next-flight service relative to the bulk of the current market (mid-morning delivery). *For the purposes of this preliminary study, we take $800/kg* as our best estimate of what shippers would be willing to pay for this service. We acknowledge that this is a somewhat optimistic choice, so we will subsequently explore this value parametrically in our economic models.

Our informal conversations with representatives of the leading shipping companies indicate that this priority segment of the market is unfortunately very small. The largest component of the market is for mid-morning delivery, with afternoon delivery following in second place. Informally, it seems that about 5% or less of express package shippers opt for the early morning delivery and only a handful opt for the custom next flight options. Still, it seems at least anecdotally that those 'desperate' shippers, few that they might be, would nearly all select a faster service if it was available. For our purposes, we assume that 80% of these urgent shippers would be willing to move to the faster service, even at the premium introduced above.

Using the FedEx international package volume data available in section 7 of the Appendix, we see that FedEx Express shipped about 181,500 kg/day of International packages in 2006. Given that FedEx controls about 21% of this market, we could estimate the total traffic to be about 865,000 kg/day of express cargo. The next question then, is what percentage of this traffic would be carried between the cities/regions identified in Table 2? Any benefits of extra speed can easily be lost if there are no airports close to the points of delivery and receipt of the package. So, the amount of demand that is eventually satisfied will depend to a high degree upon the amount of ground infrastructure that is established to support the takeoffs and landings, and speedy cargo transfers, around the world.

We can make some estimate of the nature of this relationship by looking at the distribution of airports involved in current air freight operations from the Appendix. In Section 1.3 of the Appendix, we see that, even within the U.S., the top ten gateways account for only 78% of the total demand for current international cargo. Even the single biggest cargo gateway, JFK airport in New York, accounts for only 20% of the total. The geographical distances between the top ten airports mean that the cargo traffic would not easily be transferable when the object is distribution and collection times of a few hours per region. Thus, we can assume that for a hypersonic cargo operation from the U.S., a single airport could only expect to handle about 20% of the total demand. An extrapolation to the rest of the world would suggest that multiple airports would also be needed in similarly large geographic zones to handle the regional demand in Asia and Europe. In our baseline network, we have selected two airports per continent, so we estimate that the *our baseline network of seven cities would be capable of handing only 40% of the potential size of the market* simply due to limits of the distribution and collection region and the specific intercontinental routes chosen.

So, using the rationale detailed above, we estimate that daily volume for the new service would be about:

$$\text{Volume} = (0.05*0.40*0.80)* 865{,}000 \text{ kg/day} \quad (1)$$

So worldwide volume for this service might be about 13,840 kg/day. If we very simply assume that our 30 flights each carry an equal portion of this load with one flight per day, then the *typical revenue payload on one of the new aircraft would only be about 460 kg per flight. The resultant revenue per flight, using our baseline assumptions, is therefore approximately $368,000.* The 460 kg per flight is an average number of course, and some flights might be most or less. For establishing a vehicle design requirement, we suggest a minimum capability of 1,000 kg to accommodate variation between flights and routes.

Note that we have presently ignored certain aspects of serving the market that will ultimately be important to consider. For example, what are the FAA or similar aviation regulations required to operate along these long-range routes? How can international customs operations be streamlined to fit within the new model? What are the implications for noise and other emissions? What restrictions will be placed on land overflight in general, or overall hostile countries in particular? These questions are outside the scope of our current effort, but we acknowledge that future research should address them.

VEHICLE REQUIREMENTS

Based on our assumptions, we now have enough information to formulate design requirements for a future hypersonic or rocket vehicle that might serve the market identified. Table 4 summarizes those requirements.

Table 4. Flight Vehicle Requirements.

Characteristic	Value
Minimum Payload Mass	~ 1000 kg
Payload Density	~ 45 kg/m3
Typical Flight Times	< 2 hours for most
Max Flight Range	12,000 km non-stop
Average Flight Speed	> 4,700 km/h
Turnaround Time	< 20 hours

We assume a tare weight of about 10% must be added to the minimum 1,000 kg payload to contain the packages and boxes in a pressured and thermally controlled shipping container. However, given the relatively small size of the individual packages, the larger container can be shaped to fit conformally into the flight vehicle as needed. That is, the payload shape does not drive the payload bay design toward a large box or cylinder if it is not otherwise required for the vehicle itself.

As discussed, antipodal flight ranges (20,000 km) would be desirable to serve a larger network of cities, but are not necessary for the baseline set of cities identified in this paper.

The stated turnaround time metric is a derived value assuming that each aircraft/spaceplane will fly one flight per 24-hour period. That in turn dictates a minimum fleet size of two aircraft per city pair (one flying each way per day). Faster turnaround times allow for reduced fleet sizes because they open the possibility for one aircraft to fly multiple delivery routes per day. Slower turnaround times will of course require multiple aircraft per route and increase the economic burden on the system. Based on our research a 20-hour turnaround time for reusable vehicles in this class is optimistic, but is nonetheless our baseline requirement.

We do not yet have enough information to set a requirement for maximum acceleration on the payload. Even though a large portion of the express cargo will be express envelopes, the high-value items inside the small and medium shipping boxes will almost certainly be sensitive to excessive G loads. For our own studies, we set 3 G's as an upper bound, but this value requires additional research to properly characterize.

CANDIDATE VEHICLE DESIGN

In order to evaluate the business prospects for a fast-package delivery capability, we must develop a reference concept in order to estimate representative development, production, and operating costs. There are a myriad of candidate concepts for performing this function, and it is not our intent to pick vehicle design "winners" with this study. Indeed, any concept capable of performing the mission reliably and cost effectively should be given full consideration. Several long-range flight concepts have been investigated by other research teams, and XCOR, Virgin Galactic, and Rocketplane Global have all publicly discussed their interest in serving similar point-to-point cargo markets with derivatives of their own passenger-carrying suborbital vehicles [Refs. 8 - 10].

For establishing cost, SpaceWorks Commercial developed a reference point-to-point (PTP) vehicle design concept capable of meeting the requirements outlined in Table 4. The reference PTP vehicle is shown in Figure 5. Our reference PTP Fast Package delivery concept is a remotely-piloted single-stage, hypersonic waverider-type configuration. It uses a periodic (skipping) trajectory to increase its range similar to the Silbervogel concept explored in the mid-20th century by Eugene Sanger [Ref. 16], the Soviet Keldysh bomber concept of the mid-50's [Ref. 17] and more modern periodical trajectory concepts explored at Lawrence Livermore under the HyperSoar study effort [Ref. 18]. 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 reference PTP concept 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 embedded rocket engines provide a sharp acceleration in ejector mode from takeoff to approximately Mach 3, and we continue to operate the rockets even as the inward-turning airbreathing flowpaths transition to scramjet mode. The engines therefore never enter a pure scramjet mode, rather they operate in a hybrid scram-rocket mode above approximately Mach 3. The advantage of this operating mode is that thrust can be maintained even with reduced frontal capture area, albeit at the penalty of lower overall specific impulse. Once the required cutoff velocity is reached (approximately Mach 18 - 20 for most of the baseline routes), the engines are turned off and the vehicle makes several large exoatmospheric skips, gradually slowing down with each one, until the destination is reached. If needed, the propulsion system is reignited near the end of the trajectory. Depending on range, flight time for these trajectories is easily under 2 hours.

The external airframe shape is derived from DARPA's FALCON HCV (Hypersonic Cruise Vehicle) waverider type configuration [Ref. 19] as well as the follow-on DARPA/Air Force Blackswift project [aka HTV-3X, Ref. 20]. These shapes produce a very high lift-to-drag ratio at hypersonic speeds. The SEI PTP vehicle is estimated to have a hypersonic lift-to-drag ratio of approximately 6 at an angle-of-attack of 10 – 12 degrees, a prerequisite for the skipping trajectory selected for long range. In addition to the RBCC engines, the reference concept depends on key technologies in flight controls, lightweight airframe materials, thermal protection systems, lightweight power systems, and low cost manufacturing technologies currently being advanced by government-funded hypersonics efforts in the United States, Europe, and Australia.

Part of our assumptions when estimating the cost to develop the commercial PTP cargo vehicle envisioned here, is that many of the technologies to do so will have already been demonstrated within the next 10 – 15 years by ongoing government-sponsored research and development programs. This vehicle is also designed roughly around the guidelines

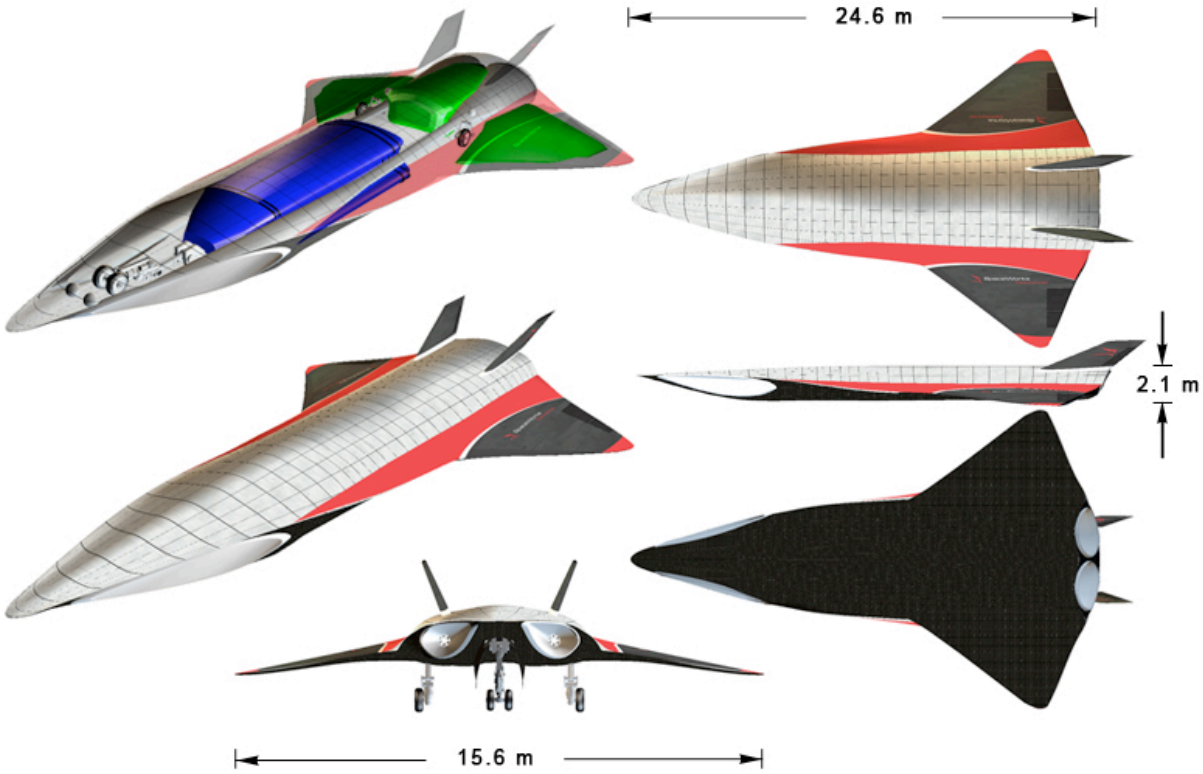

Figure 5. SpaceWorks Commercial's Reference PTP Fast Package Delivery Concept.

established for the emerging V-Prize. The V-Prize promotes a near-term commercially-developed vehicle to demonstrate transatlantic flight from the eastern U.S. to western Europe in under an hour [Ref. 21].

SpaceWorks used our Hero [Ref. 22] multi-disciplinary vehicle design and sizing environment to estimate the size and dimensions of the reference PTP concept. Aerodynamic datasets were developed using HABP, trajectories were flown in POST and visualized by TraGE-X, masses were parametrically estimated using SEI's StageSizer and the Air Force's AFWAT tool. An abbreviated Level 1 mass statement for the concept is given in Table 5. 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 based on analogies to the maintenance actions on the Lockheed SR-71 [Ref. 23]. This implies that at least two fully-staffed shifts of maintenance workers are required at each site to get the vehicle ready to fly the next day's delivery mission.

Table 5. SpaceWorks Commercial's Reference PTP Vehicle Mass Estimate.

Item	Mass [kg]
Wing Group	9,560 kg
Body Group	3,400 kg
Thermal Protection	1,440 kg
Main Propulsion	6,200 kg
Subsystems	5,400 kg
Mass Growth Margin	**4,600 kg**
Total Dry Mass	**30,600 kg**
Max Payload	**1,000 kg**
LOX	86,420 kg
JP-10 Fuel	35,285 kg
Misc. Residuals	1,435 kg
Total Gross Mass	**154,740 kg**

Sample periodic trajectories for this PTP vehicle are shown in Figures 6 and 7 at the end of this paper. As noted, we selected a remotely-piloted configuration to save mass and cost for this configuration. There are no pilots actually on board the flight vehicle, but rather they "fly" the craft from locations near the originating and departing airports. This is an emerging technology, but one that has been successfully demonstrated on military Unmanned Aerial Vehicles (UAVs).

VEHICLE COST ASSESSMENT

To begin the economic assessment of the proposed business case, we first estimate the basic costs of developing and operating a hypersonic flight vehicle such as the one described above. The cost and subsequent overall economic analysis performed here is not meant to be comprehensive or complete. It is presented as an initial set of results to help understand the economic viability of such a service using the vehicle design described in the previous section.

The proposed project has many cost elements including: Design, Development, Testing, and Evaluation (DDT&E), fleet acquisition (production) costs, facility development costs, recurring operations costs (labor, hardware, propellant, insurance, site fee, etc.), depot maintenance costs, and Selling, General, and Administrative (SG&A) costs, and financing costs. As a basis for production cost estimates, we use the Theoretical First Unit (TFU) to represent the cost of the first manufacturing unit, and then we apply a learning curve to estimate the production costs of additional units.

For DDT&E and TFU estimates, costs were estimated separately for the airframe and propulsion systems. Cost estimates were mainly based upon parametric equations taken from historical data with analogies. The NASA/Air Force Cost Model (NAFCOM) 2007 (Build Date 08/10/2007) was utilized for the non-recurring and first vehicle acquisition cost analysis. Direct hardware and overall program integration costs were calculated and included in the estimate. These wrap costs include items such as system testing, engineering, fee, margin, etc. NAFCOM is an automated parametric cost-estimating tool that uses historical space data to predict the development and production costs of new space programs.

Complexity generators in NAFCOM 2007 were used to help adjust costs relative to the perceived nature of the program. Overall, a general "skunk works" type approach was assumed when possible for subsystems, reflecting the commercial philosophy of the venture. Overall a moderate testing and qualification of subsystems at a prototype level was assumed. The program was assumed to include minimal major interfaces involving major subcontractors with minimal levels of testing and minimal level of contractors (a commercial-type philosophy).

For the cost analysis, propulsion test articles were assumed to be limited during vehicle development. We assumed only four (4) RBCC engines would be built for the testing phase of the propulsion program. Generally, the cost of each engine test article is assumed to be 120% of the TFU engine cost.

Our most significant assumption was that this development program (for both the airframe and propulsion system) would receive some benefit from other technology development programs ongoing around the world under government-sponsored research and technology maturation efforts. It is assumed that the current operation would leverage those developments and technology demos to reduce the incremental cost it would have to invest in its own development program. This would help in reducing development and acquisition costs, but would not eliminate them completely. DDT&E of a new flight vehicle would still have significant configuration-specific costs for design and testing. Programmatically, it is assumed that the operator of the high-speed point-to-point delivery service would purchase the vehicle (airframe and propulsion) from one developer.

Table 6 gives an overview of the governing schedule of the project. The first year of flight, Initial Operating Capability (IOC), is estimated to be 2020, with fleet and facilities development starting several years before IOC. We assume that there will be twenty (20) years of actual flight operations in the program.

Table 6. Programmatic Schedule.

Item	Value
Fiscal Year of Outputs	2008
Program Start Year and Fiscal Year	2014
DDT&E Start Year	2015
Number of Years of DDT&E	3
DDT&E End Year	2017
Number of Years after DDT&E ends when production/acquisition starts	0
Production/Acquisition Start Year	2017
Number of Years of Production/Acquisition	4
Production/Acquisition End Year	2020
Number of Years after Program Start when Facility Development starts	2
Facility Development Start Year	2016
Number of Years of Facility Development	5
Facility Development End Year	2020
IOC (Initial Operating Capability):	2020
Number of Flight Years In Program	20
Program End Year	2039
Number of Years In Program	26

Table 7. Non-Recurring and First Vehicle Acquisition Cost.

Item	Total
Hardware DDT&E (Airframe)	$942.0 M
Total Systems Integration	$559.2 M
Fee/Prog. Support/Cont./Vehicle Int.±	$1,174.3 M
Total DDT&E (Airframe)	**$2,675.5 M**
Hardware DDT&E (Propulsion)	$737.2 M
Total Systems Integration	$686.0 M
Fee/Prog. Support/Cont./Vehicle Int.±	$359.9 M
Total DDT&E (Propulsion)	**$1,783.1 M**
Total DDT&E (Airframe + Propulsion)	**$4,458.5 M**
Hardware TFU (Airframe)	$147.2 M
Total Systems Integration	$55.4 M
Fee/Prog. Support/Cont./Vehicle Int.±	$105.9 M
Total TFU (Airframe)	**$308.5 M**
Hardware TFU. (Propulsion) ‡	$8.8 M
Total Systems Integration	$0.9 M
Fee/Prog. Support/Cont./Vehicle Int.±	$4.4 M
Total TFU (Propulsion)	**$14.1 M**
Total TFU (Airframe + 1 Prop. Unit)	**$322.6 M**
Cost to First Vehicle (w/2 Prop. Units)	**$4,794.5 M**

† - rounded FY2008 US$, assuming a 2.1% inflation rate, any errors due to rounding
¥ - For all engines on one airframe (with 2 engines per airframe) with 95% Crawford learning/production rate effect percentage
± - Includes 10% Fee, 10% Program Support, 20% Contingency, and 4% Vehicle Level Integration in NAFCOM.

Table 7 lists the estimated non-recurring and acquisition cost for the vehicle from Figure 5. DDT&E and vehicle acquisition costs are provided along with a total cost estimate through to the first vehicle. The total first unit acquisition costs listed include minor learning effects for the propulsion systems but none for the airframe (since the first unit consists of only one airframe but two copies of the same propulsion system). 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. Programmatic costs (systems integration, fee, program support, contingency, and vehicle integration) are approximately 52 - 63% of base development and acquisition cost. This large amount represents the personnel associated with management and integration of this development project, the profit a commercial contractor will charge customer for this development, and an overall margin to account for any overruns. In terms of the base hardware cost, it can be seen that propulsion development is a large portion of development cost (40%) but a much smaller portion for acquisition cost (4%). This large

development cost for the propulsion system is due to the complexity and uniqueness of the RBCC propulsion system.

All vehicles (airframe and propulsion units) and facilities are assumed to be built at the beginning of the program prior to IOC. We recognize that this is a very major conservative assumption. Future research is encouraged to examine the most appropriate production schedule in more depth.

The minimum fleet size required for the mission scenario (5 days per week, 30 flights per business day, 52 weeks per year) is approximately thirty (30) vehicles. For added robustness and to take into account vehicle downtime (i.e. depot maintenance), thirty-five (35) vehicle airframes are acquired in the economic analysis. Similarly, even though each airframe requires only two (2) propulsion units for flight, four (4) propulsion units are acquired per airframe, providing 100% redundancy for the propulsion systems. It is assumed that all airframe and propulsion systems can be utilized during the entire span of the flight campaign over 20 years (7,800 flights per year).

Facilities development is qualitatively estimated at $250 M each for seven global facilities (learning effect of 97% on each facility). This relatively low amount reflects an assumption that local and national governments will likely make the most significant investments in any local infrastructure (e.g. runways, propellant facilities, etc.) while the PTP operating company would only need certain specialized facilities unique to its operations (e.g. a maintenance hanger and an operations facility). To recoup its investment, the local governments are assumed to charge a site fee for each landing at the new facility, similar to the gate fees charged to passenger carriers by local airports.

Table 8 has a breakout of specific recurring costs and notes their derivation in the footnote. Most of the recurring costs are qualitatively estimated or based upon some percentage of the vehicle's TFU cost. Contributors to recurring costs include: SG&A costs, a site fee charged by the local airport for landing/loading privileges, labor including maintenance personal and package handling/ operations personnel at each site, costs of spare parts and inventory (aka Line Replacement Units, LRUs), propellant costs, and hull insurance. Note that any operations cost associated with the ground segment (trucks) was assumed to use existing capacity.

Our philosophy is that the PTP operator would carry third-party replacement hull insurance on the actual airframes rather than being self-insured. The rate for this coverage is assumed to be proportional to the expected financial loss on each flight that is in turn related to the production cost and the loss of vehicle (LOV) reliability for the proposed system. For this project, we assume a LOV reliability of 1 failure in 10,000 flights. The basic cost to replace an airframe is taken to be the vehicle TFU. Estimating rates for *liability* insurance is beyond the scope of our present work. We optimistically assume that governments would bear the bulk of the expected liability from failures of such a system.

Depot maintenance is modeled as a certain fixed cost per year that is applied to every flight. There is no depot facility development cost therefore included in the non-recurring costs. We assume that this is potentially an outsourced function and its costs are therefore included as a recurring cost per flight. Annual depot maintenance cost is assumed to be 10% of the TFU cost of a complete vehicle (airframe and propulsion). This amount is smeared over all annual flights. Taking into account depot maintenance, the average recurring cost per flight is approximately $0.323 M.

Table 8. Recurring Costs.[±]

Cost Item	Per Year Cost[†]	Per Flight Cost[†, ¥]
Selling, General, and Administrative Cost (SG&A)	$306.7 M	$0.039 M
Site Fee	$390.0 M	$0.050 M
Labor	$306.3 M	$0.039 M
Line Replacement Unit (LRU)	$333.7 M	$0.043 M
Propellant Cost	$526.1 M	$0.067 M
Hull/Replacement Insurance	$298.8 M	$0.038 M
Direct Recurring	$2,161.5 M	$0.277 M
Depot Service Contract	$361.0 M	$0.046 M
Direct Recurring with Depot	$2,522.5 M	$0.323 M

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

¥ - assumes 30 flights per day for 5 business days per week for 52 weeks/year = 7,800 flights per year, for 20 years = 156,000 flights (average of 223/4,457 flights per airframe tail number per year/program, average 111/2,229 flights propulsion unit per year/program, with a fleet of 35 airframe units and 140 propulsion units)

± - SG&A: 12% of total direct recurring cost, Site Fee: $50K per flight, Labor: $175K FTE cost x 250 personnel/site for 7 global sites, LRU: 2.5% of vehicle (airframe and propulsion) TFU per year (no learning), Propellant cost: $0.023/kg for LOX, $0.304/kg for RP (50% boil-off for LOX), Hull/Replacement Insurance: Hull insurance based upon 1 in 10,000 Loss of Vehicle (LOV) x vehicle TFU, Liability insurance based upon 5% premium above base Hull insurance, Depot: Annual cost is 10% of one complete vehicle TFU (airframe and propulsion)

BUSINESS CASE ASSESSMENT

From the assumptions described in the previous sections about missions, capabilities, and costs, an economic viability analysis can now be developed. The market estimates and overall schedule constraints are used to develop a simple business case model for a vertically integrated business that obtains the flight vehicles, develops a limited number of facilities, and then operates them in regular package service between the seven cities in the network.

The model used for the economic analysis is a modified version of Cost and Business Analysis Module (CABAM) [Ref. 24]. CABAM is an MS-Excel spreadsheet-based model that attempts to model both the demand and supply for hypersonic and space transportation services in the future. The demand takes the form of market assumptions (both near term and far-term) and the supply comes from user-defined vehicles that are placed into the model. CABAM takes inputs from various other disciplinary models to generate Life-Cycle-Cost (LCC) and economic metrics. One of the major assumptions inherent in CABAM is that the project is modeled as a commercial endeavor with the possibility to separately consider the effects of government contribution, tax-breaks, loan guarantees, etc. Various input financial ratios and rates (debt-to-equity, discount rates, etc.) are needed for calculation of final economic metrics.

The user is also given the option to define their own discount rate or to use an internal calculation for the Weighted Average Cost of Capital (WACC). The purpose of these calculations is to help quantify the method of financing for this project and to determine an appropriate rate to discount the project's cash flows in order to obtain the Net Present Value (NPV). The WACC can be defined as the calculation of a firm's cost of capital by weighting each category of capital proportionately (shareholder's equity, bank loans, bonds, etc.). This is the average expected return on a firm's investments. The WACC is determined from appropriately weighting the cost of equity and the after-tax cost of debt (calculated from the tax rate and average annual real interest rate on debt). The weighting for debt and equity come from the debt-to-equity ratio (as input or determined from the projects cash flows when a static equity amount is entered). The cost of equity comes from the calculation of the equity risk premium and the risk free rate (typically the return of a "near" risk free investment like a U.S. government Treasury bill). The equity risk premium is derived from the market risk premium times the project's equity beta. The beta is a measure of risk of this project versus the overall market. The beta used here is associated with the debt-to-equity ratio. The beta of this project is determined from examination of three different industries gathered from a list of comparable companies. The industries for the nominal model include aerospace, air transport, and e-commerce. The first two industries have much lower betas than third.

Table 9 lists our initial assumptions for the financial modeling including the estimate for the Weighted Average Cost of Capital (WACC). For this notional venture, the WACC is estimated to be 15.82% The WACC is also used as the discount rate when calculating NPV. We have also assumed that there will be an incentive program from the federal government to develop such a business case. The so called "Zero-G, Zero-tax" is one such policy. For this analysis, we assume that the PTP operator pays no federal or local income taxes on the profits during the first five (5) years of flight operations.

Table 9. Financial Modeling Parameters.

Item	Value
Anticipated Future Inflation rate	2.1%
Tax Rate	35.0%
Capital On-hand at Program Start	$-
Debt-To-Equity Ratio	0.500
Average Ann. Nominal Interest Rate	7.50%
Average Ann. Real Interest Rate	5.29%
Tax Holiday Program Duration	5
No. of Years to Depreciate Fixed Assets	10
% of Non-Recurring Cost to Depreciate	80.0%
Salvage Value at End of Life	0.0%
Weighted Average Cost of Capital (WACC)	**15.82%**

Baseline Economic Assessment (Case A)

A baseline case, Case A, was developed wherein the operator buys all vehicles and facilities and operates the vehicle for 20 years with the input demand of 7,800 flights per year (30 flights per day x 5 days x 52 weeks) with a project WACC of 15.82%. Other assumptions modeled for this baseline case were consistent with the data previously presented in Tables 6 - 9.

As seen in Table 10, for this case the price is set to $800/kg. Even though the vehicle designed could potentially carry 1,000 kg, the model assumes that every flight has only 460 kg of revenue payload per our previously presented market analysis. For this baseline case, the NPV is *negative* $7,691.4 M (FY2008). For these assumption, revenue per flight in 2008 FY dollars is only $368,000 per flight ($57.4 M

over the 20 year period of operations). Once discounted by the WACC, the revenues in the out-years of operations become less significant while the near-term DDT&E, fleet acquisition, and facilities investments become dominant. There simply isn't enough revenue to make this a viable business case.

Table 10. Financial Case A.†

Item	Value
WACC	15.82%
Payload	**460.0 kg**
Price	**$800.0/kg**
Net Present Value (NPV)	**-$7,691.4 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	$10,261.7 M
Taxes	$2,499.0 M
Revenue	$57,408.0 M
Total Equity Investment	$10,059.2 M

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

Among the cost contributors, recurring operations costs are the most significant share of the life-cycle costs. Over the life-cycle, recurring costs account for over $29.3 B of expenses. From Table 8, we observe that SG&A costs, propellant costs, the site fee (landing fees at the local airport), hull insurance costs, depot services, and labor costs all contribute significantly to recurring costs. On average, recurring costs are estimated to be $323,000 per flight (about 88% of revenue per flight). While each cost contributor might be challenged individually, it is unlikely that a more refined cost estimate would result in a significant overall reduction in this estimate. Propellant costs are on the rise worldwide. Labor costs will also probably rise disproportionately in the next decade. Operating hypersonic flight vehicles will likely be expensive in terms of spare parts, hull replacement insurance, and depot services compared to subsonic airliners.

Economic Trade Studies (Cases B, C, and D)

So, we can conclude that our baseline market, vehicle design, and business case assumptions do not produce an attractive business case. One might then logically ask, what would it take to turn the economic assessment of this market positive? How far away are we from a positive business case?

We performed three trade studies to explore alternative sets of assumptions. Case B assumes that the average payload per flight is fixed at 460 kg per our market assessment, but allows the price to vary to reach a point of zero NPV (when evaluating business cases, NPV should be greater than zero. Zero is considered only a neutral investment). Case C holds the price constant at $800/kg, but allows the market size to increase to reach a zero NPV. Case D assumes that each PTP vehicle flies at its maximum design capacity (1,000 kg) and allows the price to vary to meet a zero NPV.

Table 11. Financial Case B.†

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

Table 12. Financial Case C.†

Item	Value
WACC	15.82%
Payload	**973.9 kg**
Price	**$800.0/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

Table 13. Financial Case D.†

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

For Case B (Table 11), we observe that the price would have to increase to $1,694/kg to achieve a zero NPV while keeping the market size fixed. That suggests that the same high-priority shippers identified for this market would be willing to pay over twice our previous estimate for a package to be shipped a day earlier than available by other scheduled service means. Recall however that our market assessment also included some examples of non-schedule next flight services provided by FedEx Express (Table 3). For example, current shippers can use the next available flight service to deliver a 0.6 kg box from LA to Tokyo for $476 ($793/kg). It seems unlikely that a new schedule service could compete with next flight services at a rate that is nearly twice that high.

Next we considered an increase in market size assuming a constant price of $800/kg (our original assumption). Case C is summarized in Table 12. We conclude that the business case would be positive if the market size resulted in an average load of 974 kg per flight (about 29,220 kg per day between our seven city pairs). This is over twice as much payload per day as we assumed in our baseline at this price point. In Case D (Table 13), we observe that the price per kg for a package is also close to our original assumption if the vehicle reaches its maximum capacity each flight (1,000 kg).

We established the baseline daily market volume estimate for this paper in Equation 1. However, we noted that the market size estimates for this service were best guesses. Is it possible that the market is twice as large as our initial estimate? Perhaps it is, but we strongly recommend that a formal, statistically-valid market study be undertaken to properly answer this question. This is a critical assumption that needs to be further vetted. Unfortunately, executing such a study is beyond the scope and resources available for this work.

CONCLUSIONS

Our goal in this preliminary study was to provide a definitive answer to the question "Is the world ready for high-speed intercontinental package delivery (yet)?" We nominally limited our timeframe to the next 10 – 20 years, and made several key assumptions about how the service would be operated (e.g. concentrating only on express package shipments and only on new time-definite route between seven initial cities). We hoped, even considering the relatively top-level nature of the analysis, that we could produce a clear yes or no answer based on either the business case or the technical nature of the transportation system. Unfortunately, the strongest conclusion we can presently reach is "probably not."

From a vehicle design point-of-view, there are a variety of configurations and propulsion systems that might be used to deliver cargo from one city region to another over intercontinental distances in under two hours. Simple rockets could be used, but lower recurring cost reusable solutions are probably better candidates. Our own SpaceWorks Commercial PTP reference concept relies on hypersonic RBCC propulsion and long-range periodic (skipping) trajectories. Given the strong government-led research programs in hypersonics in the U.S., Europe, and Australia, *it seems reasonable to assume that a commercial vehicle derived from these technologies might indeed be fielded in the next decade or two*. This assumes of course that these government-led development programs continue and are successful.

The economic component of our question is more difficult to answer. *Based on our initial set of assumptions for the market size, price, and associated costs of fielding and operating the system, we conclude that the business case is negative for this proposed venture.* The trade space for this project is shown graphically in Figure 8. Note that the initial economic design point is shown clearly to lie in the region with NPV less than zero. Revenue for this case is derived from 30 flights per day with an average revenue payload of 460 kg at a price of $800/kg.

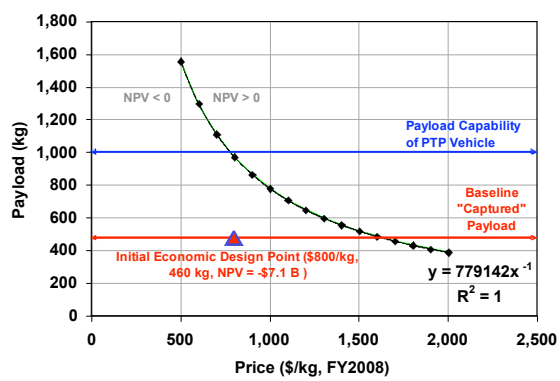

Figure 8. Combination of Price and Payload ("Captured Demand") for NPV =0 for SEI's PTP Vehicle Concept.

We can say with some certainty that it is unlikely that even a high-priority package shipper would pay more than $800/kg for a fast package delivery given option that already exist in the market for on-demand shipping options at or near that same price.

However, we are less confident in the market volume assumptions that we have currently selected as our baseline. Our estimate of 460 kg per flight (13,800 kg of packages per day between the seven selected cities) was derived from an estimate of current daily fast package volume combined with informal estimates of the fraction of shippers that would select the fastest schedule service possible and the fraction of worldwide service that would be addressed by our selected city pairs.

Without a true statistically valid market assessment, we are left to speculate on these market volume assumptions. It is obvious however, that the key to economic viability of a new high-speed delivery service will be to drive the revenue side of the analysis higher, or the cost side lower, or both. The revenue side will increase with overall demand for this service. A formal market study might help better quantify the market volume. Market research should go beyond simply addressing customers of the current next-morning fast package services. Service that is one business day faster (even same day on certain routes) might be a significant enabling capability for new classes of customers who are not currently included in the market model. Spaceport Associates would be positioned to provide such a survey if resources were made available.

On the cost side, a robust government research program in hypersonics would definitely benefit the reference concept we suggested by lowering DDT&E and production costs, but other innovative vehicle solutions might lead to still lower costs. We do not rule out the potential that a different approach to vehicle design might offer a substantial cost savings over the concept envisioned here. However, we emphasize that our own cost estimates reflect a realistic assessment of the costs of fielding a new hypersonic flight system designed to operate in regular service 30 flights per day for 20 years. This is an operational vehicle akin to a commercial aircraft, not an experimental vehicle designed for limited flights.

As a reminder, our conclusions are limited to the scope of the study and the major assumptions that we laid out throughout the paper. As discussed, the largest assumptions were developed in regards to the market demand (some conservative, some aggressive). Our estimated service price of $800/kg is thought to be optimistic. On the cost side, we have made a major assumption on the synergies between government-led hypersonic programs and the reference flight vehicle. These synergies lead to a positive effect on development costs. We have assumed that local governments will pay for required infrastructure developments and also provide some relief from liability insurance costs. We also optimistically assumed some government incentives in the form of tax relief for the initial five years of flight operations. In terms of the relationship of the proposed high-speed air segment to the supporting ground delivery segment (trucks), we have optimistically assumed that there is no incremental cost to the business case for utilizing existing ground infrastructure. That is, we assume that our business model is an overlay to existing express package delivery providers.

Other models for fast package delivery should be explored as well. The authors encourage additional research on the notion of on-demand service or potential synergies with the emerging passenger market for suborbital flight. In the latter case, potential revenue sharing and amortization of investment costs across a larger base of operations might offer some economic benefits.

FUTURE WORK

SpaceWorks Commercial is leading the organization of a new industry affinity group for the purpose of further studying the ultra fast-package delivery market. The goal of this new working group is 1) to collaborate on market and technical research and 2) share pre-competition information that might be beneficial to all parties.

We are actively seeking members of this “Fast Forward Working Group” from the vehicle design community as well as the express package shipping industry in hopes of building a broad base of expertise and knowledge that will benefit all members of the group. To date, six organizations have agreed to be members. The group hopes to conduct its work primarily through email exchange and an online group collaboration web site. In addition, we expect to host bimonthly telecoms hosted by SpaceWorks Commercial. Interested parties should contact the lead author for more information.

ACKNOWLEDGMENTS

The authors wish to thank our colleagues at SpaceWorks Commercial who contributed to this work. In particular, Jennifer (JLL) Laperre helped conceive of and implement the GHoST calculator used to determine time allowances for key fast package routes. Mark Elwood of SpaceWorks Engineering contributed to the design of the point-of-departure PTP vehicle concept introduced here.

We are also grateful to those anonymous individuals in the shipping industry who helped guide our thoughts and directions in this study.

REFERENCES

1. Compart, A., "Virgin Galactic Unveils New Mothership," AviationWeek.com, July 28, 2008.

2. Beard, S. S., and Starzyk, J., "Futron/Zogby Space Tourism Market Study – Orbital Space Travel and Destinations," Futron Corporation, Oct. 2002.

3. Stockmans, R., Collins, P., and Maita, M., "Demand for Space Tourism in America and Japan, and its Implications for Future Space Activities," AAS paper no. AAS 95-605, AAS Vol. 91, pp. 601-610, 1995.

4. Charania, A., Olds, J. R., DePasquale, D., "Sub-Orbital Space Tourism: Predictions of the Future Marketplace Using Agent-Based Modeling," IAC-06-E3.4, 57th International Astronautical Congress, Valencia, Spain, October 2-6, 2006.

5. Webber, D., "Point-to-point Sub-Orbital Space Tourism: Some Initial Considerations," AA-1-2008-053, 1st IAA Symposium on Private Manned Access to Space, Arcachon, France, May 28-30, 2008.

6. Dinerman, T., "Point-to-point suborbital spaceflight and military logistics," The Space Review, http://www.thespacereview.com/article/1103/1, April 14, 2008.

7. Martin, J., Karasi, A., Glas, D., Palmer, K., and Chan, M., "Fast Package Delivery - Commercial application of a hypersonic airbreathing vehicle," AIAA-1998-5261, AIAA Defense and Civil Space Programs Conference and Exhibit, Huntsville, AL, Oct. 28-30, 1998.

8. Martin, J. C., and Law, G. W., "Suborbital Reusable Launch Vehicles and Applicable Markets," The Aerospace Corporation, Final Report for U.S. Department of Commerce, Office of Space Commercialization Contract SB1359-01-Z-0020, October 2002.

9. Federal Aviation Administration (FAA), "Suborbital Reusable Launch Vehicles and Emerging Markets," FAA Office of Commercial Space Transportation, February 2005.

10. Belfiore, M., "The O Prize," Air & Space Magazine, Vol. 22, No. 5, pp. 36 – 41, November, 2007.

11. The Economist Pocket World in Figures: 2007 Edition, Profile Books, London, U.K., 2006.

12. "U.S. International Trade and Freight Transportation Trends," U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information Data, pp. 44 (Table 18), 2003.

13. U.S. Department of Transportation, Bureau of Transportation Statistics, 2007.

14. FedEx Historical Statistical Book (available as an Excel spreadsheet or pdf file), http://fedex.com/us/investorrelations/financialinfo/financialhistory/. Last accessed September 1, 2008.

15. Largest Cargo Airports of the World, http://www.geohive.com/charts/ec_airport2.aspx. Last visited September 1, 2008.

16. Sanger Amerika Bomber Luft '46, http://www.luft46.com/misc/sanger.html#diagram. Last visited September 1, 2008.

17. Ratliff, F., Keldysh Bomber, Son of the Antipodal, http://www.space-frontier.org/cgi-bin/BBS/CP1/read/2944. Last visited September 1, 2008.

18. Scott, W. B., "Airbreathing HyperSoar Would 'Bounce' on Upper Atmosphere," Aviation Week & Space Technology, pp. 126-128, September 7, 1998.

19. Malik, T., "Going Hypersonic: Flying FALCON for Defense," Space.com, http://www.space.com/businesstechnology/technology/darpa_falcon_030723.html. Last visited September 1, 2008.

20. Adde, N. and Iannotta, B., “The Fight for Blackswift”, *C4ISR Journal*, September, 2008.

21. “Hypersonic Cruise for the V-prize”, http://wordpress.com/tag/v-prize/. Last accessed September 1, 2008.

22. Bradford, J., “Hero: A Collaborative Multidisciplinary and Multifidelity Air-Breathing Launch Vehicle Design Framework,” Final Report for Subcontract 07-S530-0035-27-C1 to Universal Technologies Corporation (under prime contract F33615-02-D-2299 to AFRL Wright-Patterson AFB), SpaceWorks Engineering, Inc., Atlanta, GA, July 2008.

23. Bennett, C. W., A Typical SR-71 Maintenance Process, http://www.blackbirds.net/u2/c_bennett/bbird-00.html. Last accessed: September 1, 2008.

24. Charania, A., Olds, J. R., "Optimization of a Future RLV Business Case Using Multiple Strategic Market Prices," IAC-02-IAA.1.1.07, 53rd International Astronautical Congress, The World Space Congress - 2002, Houston, Texas, October 10-19, 2002.

Figure 6. Sample PTP Periodic Trajectory - London to Tokyo

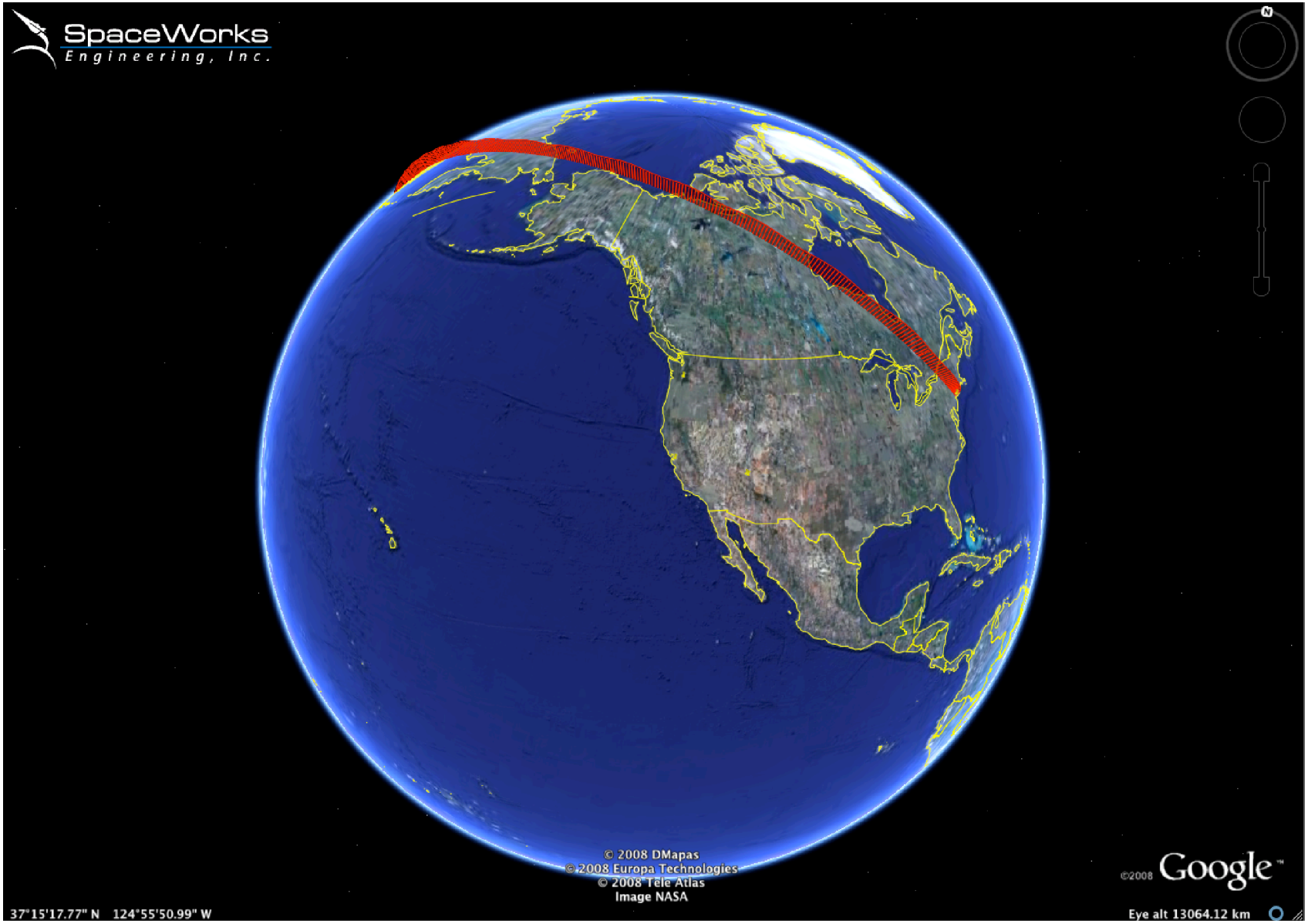

Figure 7. Sample PTP Periodic Trajectory - New York to Shanghai

APPENDIX

Air Cargo Facts Database

A1. Air Cargo Statistics

Total World Air Cargo

Total World Air Freight tons carried (Note world airline scheduled service only): 31.7M in 2001 (Ref 2, P 80)

Total Cargo World Rankings (Ref A1, P 26) top 50% in 2007:

Rank	Country	Percentage of World Exports
1	US	12%
2	Germany	9%
3	UK	6%
4	Japan	6%
5	China	5%
6	France	5%
7	Italy	4%
8	Netherlands	3%

Busiest World Cargo Airports (Ref A1, P 74) top 60% in 2007 (Note: domestic and international):

Rank	Airport	Million Tons Cargo
1	Memphis	3.6
2	Hong Kong	3.4
3	Anchorage	2.6
4	Tokyo	2.3
5	Seoul	2.1
6	Frankfurt	2.0
7	Los Angeles	1.9
8	Shanghai	1.8

Total US Air Cargo

Total US Landed Air Cargo Weight in 2006 (Ref 7): 152B lbs

Total International Cargo Trade from US Gateways, in 2001 (Ref 5, Table 18)

$682B from land, sea, airports

$251B from airports (= 36% of total)

US Scheduled/Non-Scheduled splits, (Ref 6, Table 2):

Scheduled airfreight in 2007: 7.6M revenue-tons
Non-scheduled airfreight in 2007: 5.0M revenue-tons
Scheduled airmail in 2007: 1.7M revenue-tons
Non-scheduled airmail in 2007: 0.5M revenue-tons

US Domestic/International splits, (Ref 2, p83):

Domestic Commercial Airfreight in 2001: 41%
International Commercial Airfreight in 2001: 49%
Domestic Commercial Airmail in 2001: 7%
International Commercial Airmail in 2001: 3%

US Cargo Airport Rankings

Top US Air Gateways (78% of total) for International Cargo Trade in 2001 (Ref 5, Table 18)

Rank	Airport	Exports ($B)
1	JFK	50
2	LAX	34
3	SFO	32
4	Chicago	20
5	New Orleans	14
6	Miami	15
7	Anchorage	5
8	Cleveland, OH	9
9	DFW	9
10	Atlanta	7

Top Air Cargo Airport Pairs

Top airport pairs for US International Air Freight in 2000 (Ref 5, Table 20)

Rank	From	To	Airfreight (in thousands of short-tons
1	Anchorage	Tokyo	523
2	Anchorage	Seoul	471
3	Anchorage	Taipei	404
4	Anchorage	Osaka	211
5	Miami	Bogota	157
6	Anchorage	Hong Kong	137
7	JFK	Brussels	126
8	JFK	LHR	126
9	JFK	Frankfurt	104
10	SFO	Tokyo	103
11	LAX	Seoul	100
12	Chicago	Frankfurt	93
13	LAX	Tokyo	79
14	SFO	Seoul	78
15	Chicago	LHR	77

A2. Air Freight Companies

US Airfreight Company Rankings in 2007 (Ref 3, P 395):

Top 30% Top 87%

Rank	Company	Share of Global Airfreight	Share of Int'l Air Express
1	Fedex	9.3%	20.7%
2	UPS	5.9%	19.6%
3	Lufthansa	5.0%	-
4	Singapore	4.9%	-
5	Cargo Lux	3.3%	-
6	Nippon Cargo	1.6%	-
...			
10	EAT	-	34.9%
11	TNT	-	11.7%

FEDEX Data (Ref 3, P 396)

Address: PO BOX 727, Memphis, TN 38194, USA
Tel: (901) 369 3600
Pres/CEO: David J Bronczek
Jet Freighter Fleet: 344 aircraft
Freight Tons Carried: 7.7M tons in 2006
Revenues: $32.2B in 2006 (Ref 4, P72)

UPS Data (Ref 3, P 397)

Address:
55 Glenlake Parkway, NE, Atlanta, GA 30328, USA
Tel: (404) 828 6000
CEO: Michael L. Eskew
Pres: John Beystehner
Jet Freighter Fleet: 282 aircraft
Freight tons carried: 4.6M tons in 2005
Revenues: $47.5B in 2006 (Ref 4, P72)

A3. Classifications of Air Cargo

Technical Categories

Freight – Containers

- 20 ft containers have 42,000 lb max capacity (Ref 8)
- Full containers go at Full Container Rates (FCL)
- Partial Containers go at Less than Container Rates (LCL)
- Air Cargo Rates – Below 500lbs, Air cargo rates are lowest cost (Ref 9)
- IATA encourages high density packing (Ref 9) using 166 cubic inches/lb as the guide, referred to as "Volumetric Standard" or "Dimensional Weight" (Ref 11).

Packages

- Maximum weight of any single package is 200lb (Ref 10)
- Package size may not exceed 90 total inches (length + breadth+ width) (Ref 10)
- Density guideline is 166 cubic inches/lb (Ref 9)

A4. Logistical Aspects of Air Cargo

Regulation

Aircargo is regulated by TSA, FAA, DoT and others (Ref 8). To be an operator in this business, it is necessary to have multiple licenses. There is the need to take account of the ITAR process as part of the work on legality of exports. The air cargo business has multiple classes of operator, including brokers and air carriers. For an organization to become a regular shipper of export products, the TSA must vet the company, and then the shipper becomes a "Known Shipper". This process takes 7 days (Ref 10).

Insurance

There is generally a $9.07 per pound liability limit for insurance as the basic level of cover, unless more is purchased. (Ref 9). Generally speaking, commercial cargo insurance costs less than personal effects insurance.

Customs

As a consequence of the Homeland Security Act, enforcement of procedures is strictly carried out (Ref 8). All shipping documentation must be prepared prior to loading. Above a value of $2500, a Shippers Export Declaration Form (SED) is required.

Airbills

Ref 8 provides a good listing of the contents of Airbills and other shipping documents, and the allocation of Tracking Numbers.

Advance Booking

In the case of Aircargo, between 4 to 48 hours is needed to book and confirm the shipment (Ref 8).

Packing

Additional charges are added if the customer does not do this.

Pickups

- Additional charges are added for pickups from the customer premises (Ref 10).
- Care must be taken to allow for Cutoff Times before a flight. Airbill and inspection must be completed before a shipment can be loaded on a Next Flight Guaranteed transport.

A5. Pricing

Packages

Some examples of 2008 FedEx package pricing are provided, from Ref 11. FedEx offers three classes of international package delivery, with prices increasing dramatically with speed. There is a basic charge for 1 lb package delivery, then additional incremental charges to cover heavier packages. The examples chosen cover an East Coast to Europe route, and a West Coast to Asia route:

Route	Weight	Int'l Priority	Int'l First (Europe Only)	Int'l Next Flight
JFK-Brussels	1 lb	$53	$98	$365
	10 lb	$130	$175	$465
	50 lb	$338	$383	$865

(Note: incremental $10/ lb)

Route	Weight	Int'l Priority	Int'l First (Europe Only)	Int'l Next Flight
LAX-Tokyo	1 lb	$52	n/a	$476
	10 lb	$130	n/a	$490
	50 lb	$338	n/a	$737

(Note: incremental $14.75/lb)

Data for UPS International package delivery services is available at www.ups.com. There are four classes of service to Europe for time-definite service with different guaranteed delivery times.

Route	Weight	Worldwide Expedited	Worldwide Saver)	Worldwide Express	Worldwide Express +
NYC - Cologne	1 lb	$104	$110	$114	$168

Additional charges: In addition to the basic rates above, there are a number of extra services that would result in increased charges, including:

- Handling
- Ancillary Clearance Service fees
- Broker Selection
- Change of Air Waybill
- Pickup Charge
- Duties and Taxes
- Fuel Surcharge
- Rural Delivery charge
- Saturday Delivery charge, etc, etc.

Freight

Some examples of Freight pricing are provided from Ref 9, where it is pointed out that "for a given destination, the heavier the shipment, the lower the rate per pound". This reflects a pricing structure where there is an initial high charge for the basic service, then low incremental rates per lb beyond the basic shipment size, up to a maximum.

California to Germany	300 lb shipment	$1.05/lb
Georgia to Guatamala	850 lb shipment	$0.43/lb
Chicago to South Africa	250 lb shipment	$2.20/lb

A6. Shipper Viewpoint

Interview on June 25, 2008 with Shipping Manager at Kinkos store in the Washington DC area offering Fedex Services:

Store address: Fedex/Kinkos, 11560 Rockville Pike, Kensington, MD

"From here, the Same Day service covers US domestic only"

"The Next Day International service covers some European destinations only"

"I have never lost any business because we could not ship something fast enough, but sometimes customers do say – Can you not deliver it Next Day? I guess what we offer is fast enough."

"You are asking about faster service? You are talking about sending cargos via space? Then you are talking to the wrong people – you should be talking to Virgin Galactic!"

A7. Revenue Breakdown

Reference 12 provides useful information on the mix of cargo types and the relative quantities of each type for the FedEx Express Segment. The following data are presented for year 2006 (although the original data

source provides a multi-year track, for future reference):

Revenues

Package Revenue – Int'l Priority	$6.1B
Package Revenue – US	$11.2B
Package Revenue – Total	$17.3B
Freight Revenue –US	$2.2B
Freight Revenue – Int'l Priority	$0.8B
Freight Revenue – Int'l Airfreight	$0.4B
Freight Revenue - Total	$3.4B

Avg Daily Volumes

Avg Daily Package Volume – Int'l Priority	0.4 M lbs
Avg Daily Package Volume – US	2.8 M lbs
Avg Daily Package Volume – Total	3.2 M lbs
Avg Daily Freight Volume – US	9.3 M lbs
Avg Daily Freight Volume – Int'l Priority	1.6 M lbs
Avg Daily Freight Volume – Int'l Airfreight	2.1 M lbs
Avg Daily Freight Volume – Total	13.0 M lbs

Yields (Rev per unit)

Revenue per package – Int'l Priority	$51
Revenue per package – US	$15
Revenue per package – Total	$20
Revenue per Freight Pound – US	$0.9
Revenue per Freight Pound – Int'l Priority	$2.0
Revenue per Freight Pound – Int'l Airfreight	$0.8
Revenue per Freight Pound – Total Composite	$1.0

A8. References (Appendix)

1. The Economist Pocket World in Figures, 2007.

2. Aerospace Facts and Figures – AIA 2002/2003 Edition.

3. Aerospace Source Book 2007 – Aviation Week and Space Technology, McGraw-Hill.

4. Aviation Week and Space Technology, July 16, 2007.

5. US International Trade and Freight Transportation Trends, 2003, US DoT, Bureau of Transportation Statistics, Office of Airline Information Data.

6. US DoT, Bureau of Transportation Statistics, 2007.

7. FAA – CY06 ACAIS All Cargo Data, 2006.

8. www.Shipping-Worldwide.com.

9. www.Logisticoninc.com.

10. www.swacargo.com.

11. www.fedex.com.

12. Fedex Historical Statistics Book (via Fedex website).