# *StarBooster* ™ *ISS Service Module*

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### Abstract

The *StarBooster 200*™ reusable booster is described, along with the upper stages required to deliver both *Delta III/H-2* class low orbit payloads and large communications satellites to their preferred orbits. An upper stage complex named *StarCore I*™, which is topped by a *Centaur* stage, delivers over 3 tons to the geo-stationary circular orbit when aided by dual *StarBooster 200*™ boost.

When fitted with an *ISS Service Module*, the dual *StarBooster 200*™*/StarCore I*™ vehicle can deliver the full 9 tons structural capability of *Centaur* to the *ISS* orbit, with significant residual propellants remaining for other uses, including re-boost of the *ISS*.

The *ISS Service Module*, when docked to the *ISS*, provides intra-vehicular (shirt-sleeve) access to 11 $m^3$ of storage lockers and freezers and to the *Centaur* avionics suite for salvage of high value items before separation for re-entry. 1.7 $m^3$ of high pressure fluid storage is available in 15 pressure vessels, connected to the *ISS* by fluid lines extending to the docking interface quick disconnects.

The *StarBooster 200*™ system will begin the era of technically sound and cost-effective reusable launch vehicles and will evolve to include both partial and fully re-usable cryogenic second stages, extending to a passenger-carrying vehicle called *StarBird I*™.

### *StarBooster 200*™

Reusable systems are needed to reduce today's high cost of launch services. *StarBooster 200*™ addresses this need by recovering the largest element of a space launch vehicle, the booster, for re-flight to support many succeeding missions. It is an aircraft with a fuselage cavity to house the complete first stage of the *Atlas III* expendable launch vehicle. It is launched vertically, powered by the *RD-180* engine, carries its payload to a staging velocity above Mach 5 at 45 to 50 kilometers altitude, separates, turns, descends, air-starts two air-breathing turbine engines, and cruises at subsonic speed to return to the launch site. It lands horizontally on wheeled landing gear at 280 km per hour (150 knots), is inspected, refurbished, mated with a new payload ensemble, and re-flown.

The simple, un-pressurized *StarBooster 200*™ airplane is 40 meters long, with a wingspan near 20 meters, modified delta wing area of 45 square meters, and has an expected empty mass of about 31 tons (68,500 pounds), including a 30% design mass margin. For comparison, empty Boeing *737* airliners weigh 27.1 to 42.5 tons and are 28.7 to 42.1 meters in length, depending upon the model number. At booster engine cut-off (BECO), the reusable *StarBooster 200*™ mass is about 53 tons, including the spent *Atlas III* first stage and 7.7 tons of jet fuel for return flight. Propellant capacity of the *Atlas III* first stage is about 203.5 short (English) tons, hence the "200" designation.

Construction is largely of aluminum alloy, thickened sufficiently to absorb the heating of ascent flight and re-entry by thermal capacitance ("heat sink") and is provided with high temperature metallic leading edges and a nose cap where high heating rates or total heat load require. The lower fuselage contains two structural beams providing much of the necessary vehicle stiffness and several "hard points" for attachment to the payloads.

Figure 1 *StarBooster 200*™on Return Flight

The payload capability and cost-effectiveness of numerous expendable launch vehicles can be multiplied by launch with the assistance of one or two *StarBoosters*. To visualize the impact, consider that the launch has moved to an altitude near 50 kilometers at a velocity of Mach 5 relative to the Earth's surface.

## The *StarBooster 200*™ System:

For example, the relatively inexpensive Lockheed Martin *Athena II* vehicle can now deliver payloads of about 1.65 tons to low Earth orbit. When aided by a single *StarBooster 200*™, its allowable payload increases to nearly 6 tons, a 250% increase.

When *Athena II* is launched by dual *StarBooster 200*™s, payload to low Earth orbit increases to well over 10 tons, placing it in the class of the *Delta III*, *Ariane 4*, and *H-2* vehicles. With this capability, it becomes possible to add a "kick stage" to deliver payloads approaching 4 tons to the geo-transfer orbit. This payload is above that of the *Atlas IIAS* and all but the two largest of the *Ariane 4* series, and is near that of the new *Atlas III*.

Figure 2 *Athena II* launched by dual *StarBooster 200*™ fully reusable boosters

Impressive as is this performance, it is below what is needed to hit the "sweet spot" of modern communications satellites: 5 to 6 tons to the geo-transfer orbit.

No present commercial launch vehicle can achieve this performance. Major upgrades of the *Ariane V*, the *H-2*, and *Proton* are in progress to achieve this capability, as well as USAF-supported development of the *Delta IV* and *Atlas V Evolved Expendable Launch Vehicles (EELVs)* and, in Russia, development by Krunichev of the new *Angara V*.

The price of these expendable vehicles is now expected to range from a low of (perhaps) \$60 millions to well over \$100 millions.

During a meeting on August 3, 1998, a senior aerospace executive made the statement to us that, if *StarBooster* was to be a contender, it must hit the “sweet spot” of at least 5 tons to the geo-transfer orbit. This challenge was fulfilled shortly thereafter with the definition and performance analysis of dual *StarBooster 200* flight with *StarCore I*™.

*StarCore I*™ consists of two *Castor 120* solid rocket motors from *Athena II* with the *Centaur* stage and *Extended Payload Fairing* from *Atlas III*. Its performance of 3.25 tons to the geo-stationary circular orbit, confirmed by the industry standard POST program, exceeds this requirement, as it is equivalent to more than 6 tons to geo-transfer.

Figure 3 dual *StarBooster 200*™ plus *StarCore I*™ launch

## The *StarBooster ISS Service Module*™

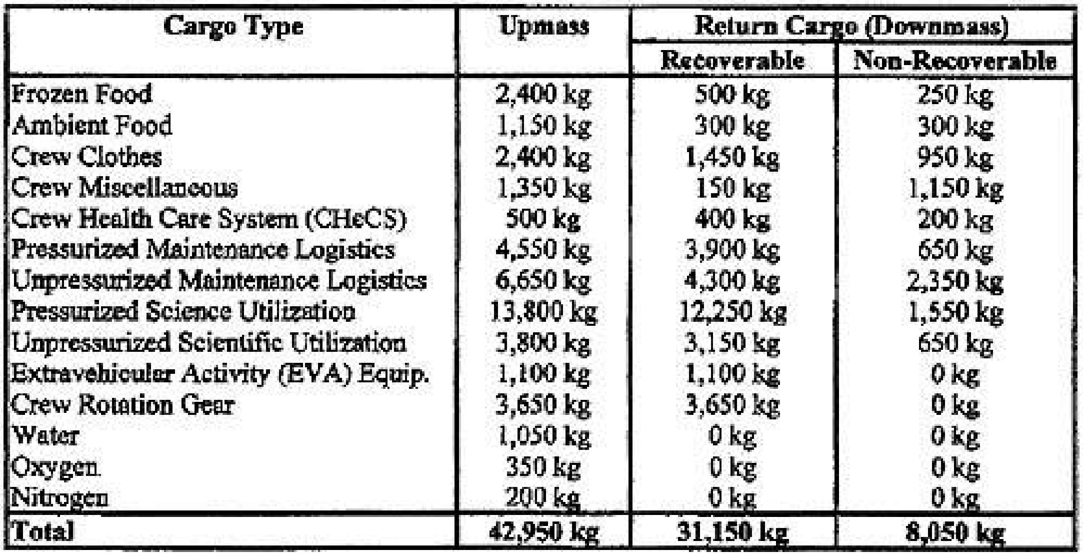
The manner in which the POST trajectory was performed led to consideration of *StarBooster* for servicing the *International Space Station (ISS).* Payload to low Earth orbit was iterated in POST until there were sufficient propellants remaining in the *Centaur* stage to transfer that payload to the geo-stationary circular orbit.

Lift-off mass of dual *StarBooster*s and *StarCore I,* including the geo-stationary circular orbit payload of 3.25 tons, was 622.7 tons. Of this, 13.36 tons (2.14%) was placed into low orbit. This consisted of the payload, the *Centaur* stage inert mass and residual propellants in the *Centaur* sufficient for the two-burn Hohman transfer to the circular operational orbit. Trade studies indicated that if all of the *Centaur* propellants were to be consumed, payload of about 15 tons could be placed into orbit (almost 2_ % of lift-off mass). However, the current *Centaur* stage structurally limits payloads mounted to its nose to about 9 tons. Thus, delivery of several tons of residual propellants to orbit along with the 9 tons of payload is necessary if the full capability of the system is to be used.

As the *RL10* engine of the *Centaur* produces water vapor and hydrogen as exhaust products, it may produce less contaminating exhaust plumes than do other propellant combinations considered for re-boost of the *ISS*. This alone can be a strong motivation for considering this form of re-boost. As the *RL 10A-4* rocket engine produces 99 kN (22,300 pounds) of thrust at full power, an acceleration of 0.05 gravities would be experienced by the fully assembled *ISS*. Either normal or deep throttling may be required to avoid excessive loads. As the *RL10* has been deep-throttled in earlier years on the test stand, this additional feature should be feasible.

Of equal importance is the ability of the system to deliver dry cargo and fluids to ISS. October, 1998 requirements for *ISS* re-supply were as indicated below:

Table I *ISS* Annual Servicing Requirements



| Cargo Type | Upmass | Return Cargo (Downmass) | |
|---|---|---|---|
| | | Recoverable | Non-Recoverable |
| Frozen Food | 2,400 kg | 500 kg | 250 kg |
| Ambient Food | 1,150 kg | 300 kg | 300 kg |
| Crew Clothes | 2,400 kg | 1,450 kg | 950 kg |
| Crew Miscellaneous | 1,350 kg | 150 kg | 1,150 kg |
| Crew Health Care System (CHeCS) | 500 kg | 400 kg | 200 kg |
| Pressurized Maintenance Logistics | 4,550 kg | 3,900 kg | 650 kg |
| Unpressurized Maintenance Logistics | 6,650 kg | 4,300 kg | 2,350 kg |
| Pressurized Science Utilization | 13,800 kg | 12,250 kg | 1,550 kg |
| Unpressurized Scientific Utilization | 3,800 kg | 3,150 kg | 650 kg |
| Extravehicular Activity (EVA) Equip. | 1,100 kg | 1,100 kg | 0 kg |
| Crew Rotation Gear | 3,650 kg | 3,650 kg | 0 kg |
| Water | 1,050 kg | 0 kg | 0 kg |
| Oxygen | 350 kg | 0 kg | 0 kg |
| Nitrogen | 200 kg | 0 kg | 0 kg |
| **Total** | **42,950 kg** | **31,150 kg** | **8,050 kg** |

The *Space Shuttle* crew rotation missions will accommodate much of these “Upmass” needs and most of the payload to be returned to Earth.  What remains to be delivered, and the “Non-recoverable” mass to be disposed of, must be provided by other means. Due to its expected highly competitive launch costs, the *StarBooster ISS Service Module*™ is considered to be a strong candidate for these missions.

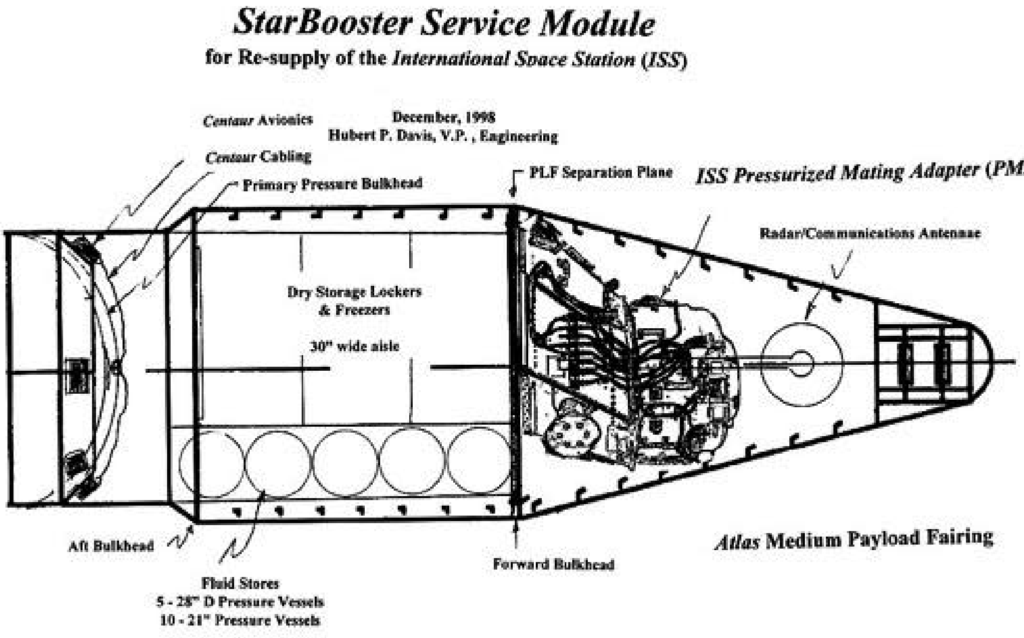


Figure 4 *StarBooster ISS Service Module*™

The pressure vessel structure is stainless steel sheet, made on the same tooling as is used to produce the *Centaur* tanks.  The *Atlas* payload fairing is modified to retain the cylindrical portion to provide protection from orbital debris and thermal excursions.  One atmosphere of pressure is maintained by a combination of the forward hydrogen tank dome of the *Centaur* stage and a new, low pressure differential bulkhead containing thermal insulation, and by a new, flat forward bulkhead with an access hatch. Lockers, freezers, and under-floor stowage compartments are accessible after docking, maintaining a 0.75 meter  (30 inches) clear passage.  Pressure bottles mounted beneath the floor contain water, nitrogen, propellants, etc.  Oxygen might be drawn from residual *Centaur* propellants or carried in some of these 15 bottles.

As an option, the *Centaur* avionics may be made accessible for on-orbit scavenging of high value elements not needed for separation and de-orbit.

The docking element illustrated is the *Pressurized Mating Adapter*, but it is an overly complex and heavy device for the intended purpose.  A much simpler docking module will almost certainly be used.

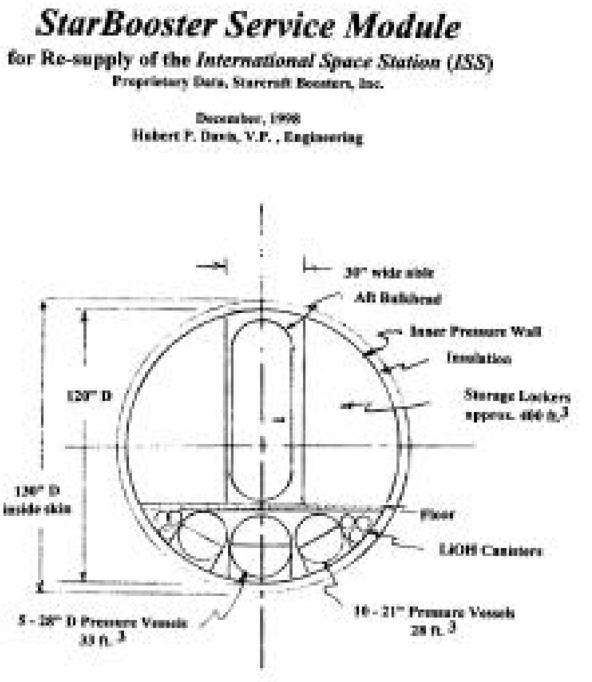


Figure *5 StarBooster Service M*odule™ cutaway end view

## Wrap-up:

The *StarBooster 200*™ system first suggested by Astronaut Buzz Aldrin in 1995 has been the topic of almost four years of evolution and analysis. It is capable of introducing reusable launch services quickly and at low risk. Due to its use of existing systems: *Atlas III* and *Athena II*, its development is reduced to designing and building an aluminum, un-pressurized airplane roughly the size of the smallest Boeing airliner - - the *B-737,* modifying the LC-41 launch pad, and performing the necessary systems engineering and integration tasks. It can be designed and produced quickly, can be flight tested first as a turbofan powered subsonic airplane, can use rocket propulsion for solo flight for incremental build-up of its flight envelope to its maximum velocity above Mach 5.

Once operational, it can economically serve commercial space launch needs, including the largest presently planned communications satellites, can deliver them directly to their operational, circular orbit without the need for apogee kick motors or spin stabilization. Alternatively, it can deliver the new satellites equipped with electric propulsion systems to “super-synchronous” orbits to increase their net useful mass on station.

If this system is developed and if it captures its share of the commercial space launch market, it will be a contender to provide re-supply to the *International Space Station*. Further definition of the *StarBooster ISS Service Module*™ is a natural and promising addition to its capabilities, and to economical maintenance of the *ISS*.