

# **Shuttle Variations And Derivatives That Never Happened - An Historical Review**

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**While the Space Shuttle was under detailed development and fabrication, we at the former Rockwell International looked at ways that the Shuttle system could be further developed by using the system elements in new ways. These involved "slicing and dicing" the Shuttle system elements in new ways and combinations that used almost everything in one unique way or another. Concepts that we looked at included stretching the orbiter, carrying a very large number of passengers, using the aft fuselage as a recoverable module, and the development of liquid rocket boosters to replace the baseline Solid Rocket Boosters. Reusable Launch Vehicle (RLV) concepts and system architectures have been explored before and subsequent to the Space Shuttle development and operation. Future studies have this design database available from which to depart. This history could be an important consideration in the forthcoming era of space exploration announced by the President.**

## **I. Introduction**

Back in the latter 1970s, while the Space Shuttle was under detailed development and fabrication, we at the former Rockwell International looked at ways that the extremely large investment in the Shuttle system could be further capitalized upon by using the system elements we were developing in new ways. These involved "slicing and dicing" the Shuttle system elements in new, unusual, and innovative ways and combinations that used almost everything in one unique way or another - some rational and others somewhat less so.

Concepts that we looked at included stretching the orbiter, carrying a very large number of passengers, using the aft fuselage as a recoverable module, and the development of liquid rocket boosters to replace the baseline Solid Rocket Boosters. Some of these studies were conducted under contract while others were in-house feasibility studies. Reusable Launch Vehicle (RLV) concepts and system architectures have been explored over the years since the early 1960s and encompassing the years before and subsequent to the Space Shuttle development and operation. Future studies have this design database available from which to depart for design of future RLVs and for the definition of their design goals.

The development of the Shuttle system has been documented intensively, so I won't even try to relate that. However, some of the background and development story in a monograph that the first author coauthored<sup>1</sup>.

The next few years were spent looking at how the orbiter and launch system could be sliced and diced to improve performance, make it do different things, and finding out how to use the various configuration elements to make new concepts without changing their designs too much. This path took us in many directions.

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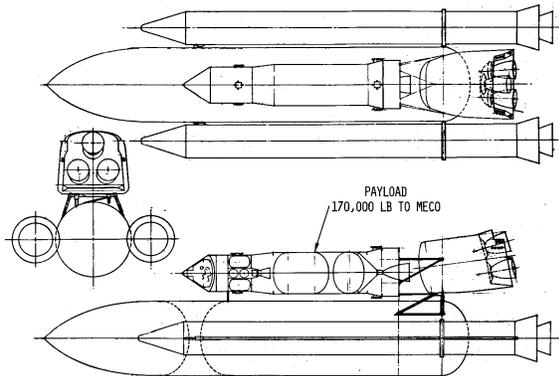
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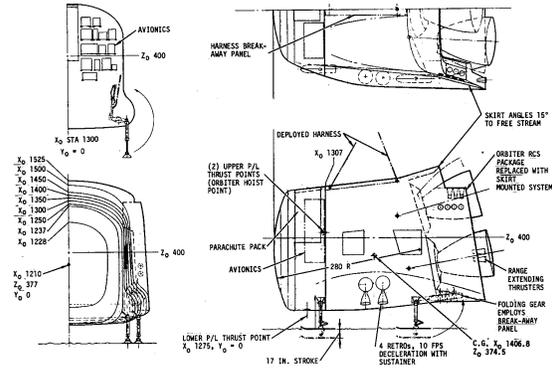
## II. Orbiter Element Options

First off, we started looking at the use of the orbiter aft fuselage as a recoverable propulsion/avionics pod. In its simplest form, we wrapped a TPS shell around the pod and recovered it ballistically. This allowed us to place payloads in front of the pod for delivering payloads to higher destinations or to lift more mass to low orbit. Thus, we gave birth to the first of a long line of Shuttle-derived heavy lift launch vehicles (HLLV), ultimately ending up with the Shuttle-C.

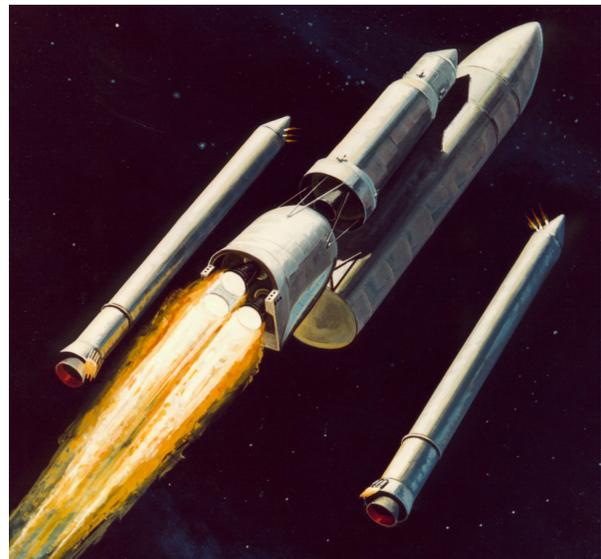
There were two basic versions: the “plain vanilla” (Fig. 1), which was a ballistic recovery pod; using parachutes and retro rockets for recovery. We estimated the delivery of combined payload and stages of up to 170,000 lb to LEO (Figs. 2 & 3).



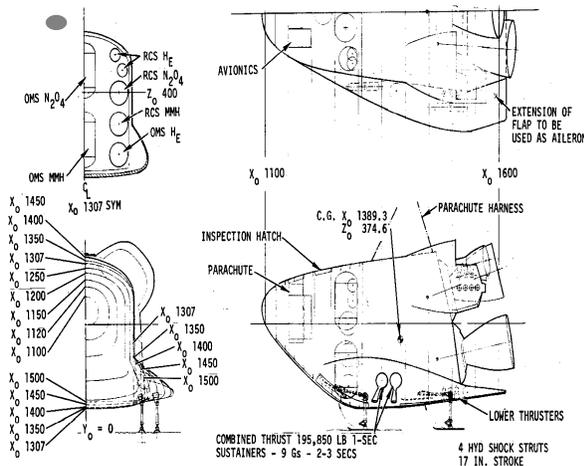
**Figure 2. Baseline Heavy Lift Launch Vehicle With Ballistic Aft Fuselage Propulsion Module. (Courtesy Boeing)**



**Figure 1. Orbiter Aft Fuselage Modified As a Recoverable Propulsion Module For a Heavy Lift Launch System. (Courtesy Boeing)**



**Figure 3. HLLV Launcher During Ascent. (Courtesy Boeing)**



**Figure 4. Propulsion Module Modified To Add Entry L/D For Crossrange. (Courtesy Boeing)**

Using the ballistic pod, we predicted recovery of the pod in the Australian outback or in northern Mexico. Since these were both very remote areas, we developed a lifting pod concept (Fig. 4) which enabled a little cross range during entry and recovery in more accessible areas but at reduced delivery masses

True to the meat packing industry of using “everything but the oink”, we didn’t leave the crew module alone. Using the crew module as a point of

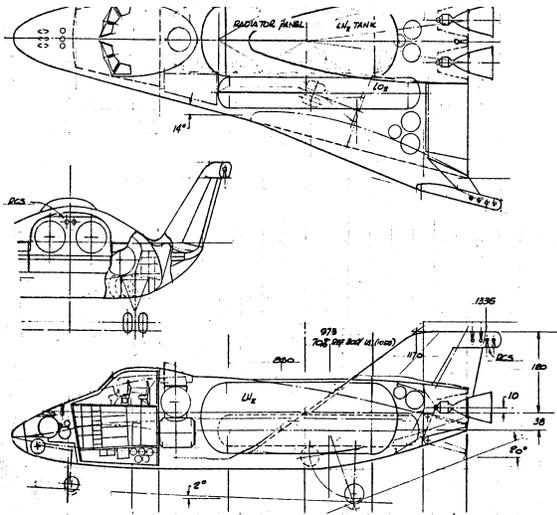


Figure 5. Orbiter Forward Fuselage Used As the Front End of a Lifting Body Configured As a Space Command Post. (Courtesy Boeing)

departure, we added an aerodynamic shape to the module and transformed it into a lifting body shape (Fig. 5). This could be used as a space-based military command post, among other things. In line with this, I generated a series of “harmonic” lunar orbits which used the moon’s energy to lift the command post to orbits around the combined Earth/moon system.

### III. External Tank & Solid Rocket Booster Options

An early study looked at a wide variety of alternate booster and external tank (ET) concepts. Under that study, we looked at a wide variety of options which are summarized in Fig. 6 and include:

- SRM options that placed the SRBs inline but aft of the ET
- Liquid rocket boosters, both hydrogen and propane to replace the SRBs
- Twin and catamaran flyback boosters to replace the SRBs
- An engine pod aft of the ET fed from twin fuel tanks where the SRBs would normally be located

ET OPTION		REUSABLE BOOSTER OPTION		WATER RECOVERY				LAND RECOVERY														
		BURN MODE	ET CODE	IMPROVED SRM	TWIN	TANDEM	INTEGRAL IN-LINE	TWIN	CATAMARAN LRB	TANDEM												
BASELINE	PARALLEL BURN	D	(1 SP B-0)	1 LH B-0 1 HC B-0 1 BE B-0	NA	NA	2A LH R-0 2A HC R-0 2A LH T-0 2A HC T-0 2A LH C-0	2B LH C-0 2B HC C-0	NA													
										EXPENDABLE	SERIES BURN	E	NA	5 LH B-E 5 HC B-E	3 LH B-E 3 HC B-E 3 LH B-E 3 HC B-E 3 FT B-E	NO ADVANTAGE	4 LH C-E 4 HC C-E					
																		PARALLEL BURN	E	NA	10 LH BEM-E 10 HC BEM-E 10 FT BEM-E	NA
REUSABLE	SERIES BURN	R	NA	6 LH B-R 6 HC B-R	NO ADVANTAGE	8 LH R-RX 8 LH T-RX 8 LH C-RX	9 LH C-RX															
								CROSS FEED	RX	NA	7 LH B-RX	NA	NA	8 BE C-RX	9 BE C-RX	NA						

Figure 6. A Wide Variety of Booster, External Tank, and Propellant Options Were Studied. (Courtesy NASA/MSFC)

- In-line integrated booster/ET with a recoverable aft engine pod
- Tandem boosters and ETs in a variety of recoverable concepts
- Single booster with multiple ETs (expendable and recoverable)

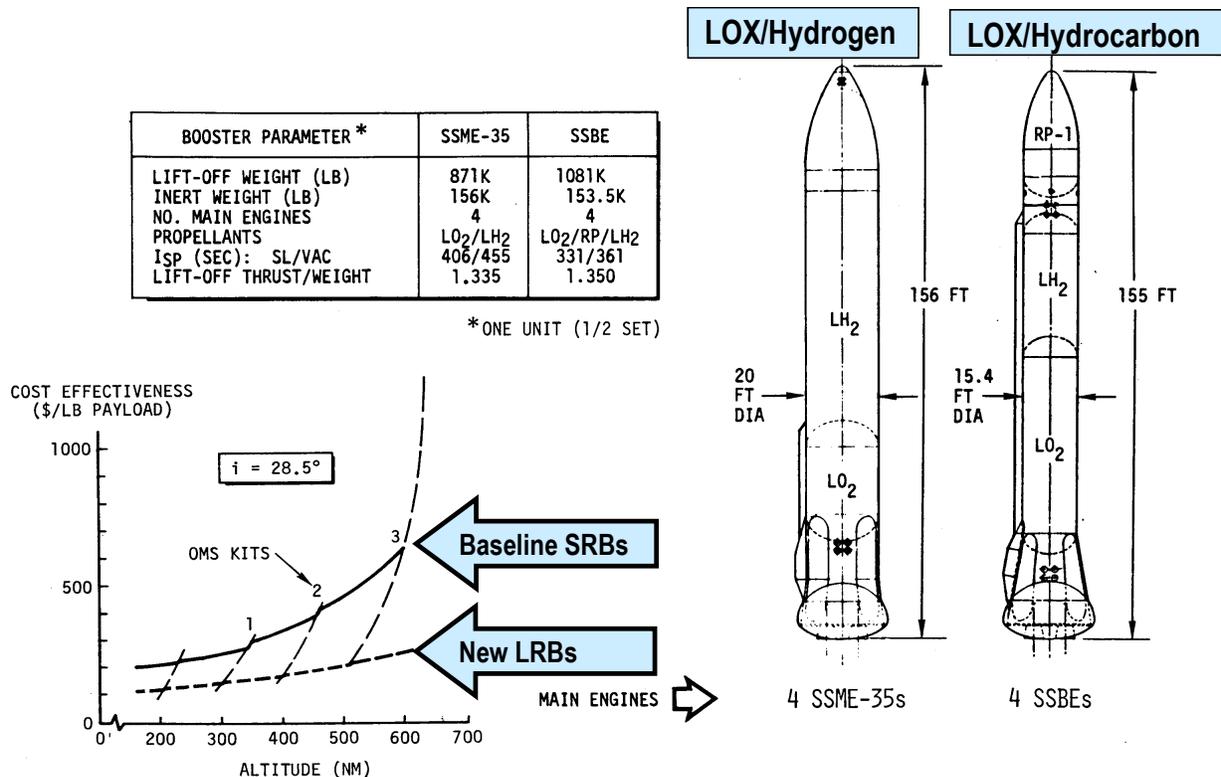
This set us off in several directions. The liquid boosters became the design objective of the NASA/MSFC Shuttle Growth Study contract<sup>2</sup>. This was probably the first definitive study of booster replacements for the Shuttle system. They were to be water-recoverable and used clam shell doors to protect the engines from salt water immersion. The boosters (Fig. 7) were sized for a “fictitious” orbiter that had 100,000 lbs payload capability (more on this later).

Flyback boosters reemerged about twenty years later in the NASA Liquid Flyback Booster Study. Most of the other arrangements eventually died out as not being overly effective, or even logical. The Shuttle Growth Study built on this background by developing design concepts in great detail for the liquid rocket boosters.

A study conducted for DARPA<sup>3</sup> addressed the idea of modifying the ET to carry large low density payloads to orbit. We examined modifications to carry 7.6 to 10.6 meter diameter payloads to LEO (Fig. 8). The first was a cylindrical extension to the ET and required that the oxygen tank be redesigned into a cylindrical tank. The revised external tank was configured with a payload bay directly in front of the tank. This provided that capability to carry payloads of 7.6 meters diameter. Larger diameter payloads required the development of a hammerhead payload compartment forward of the cylindrical oxygen tank (Fig. 9).

The orbiter was to be launched with its internal payload bay empty in these modes. The new payload compartment opened and deployed the payload via clamshell doors (Fig. 10).

Later in-house studies used the HLLV to show how very large diameter telescopes could be launched and assembled in space. These ranged from 7.6 meters (Fig. 11) to 20 meters. The latter had a primary mirror that was integral with a lenticular shell that was launched with an HLLV (Figs. 12 & 13).



**Figure 7. Liquid Boosters Have The Capability To Significantly Reduce Operational Costs. (Courtesy NASA/MSFC)**

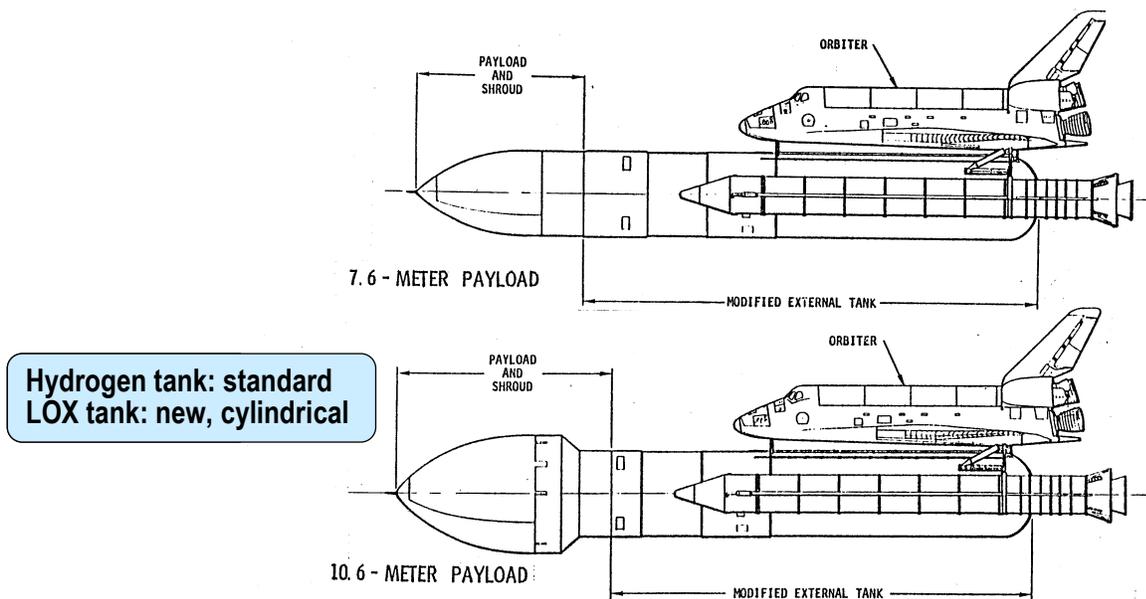


Figure 8. Large Low Density Payloads Could Be Carried In Extensions To The External Tank. (Courtesy DARPA)



Figure 9. 10.6 Meter Diameter Hammerhead Configuration At Launch. (Courtesy DARPA)

One very brief exercise took this elliptical body of revolution and provided internal compartments so that it could become an element of a space station. Only a few cartoons were made of these extremely large diameter payload ideas (Fig. 13).

Upper stages for the HLLV were developed along several lines. Some were conventional propulsive stages destined for higher orbits. Others were simply the unpowered payload bay section of the orbiter coupled

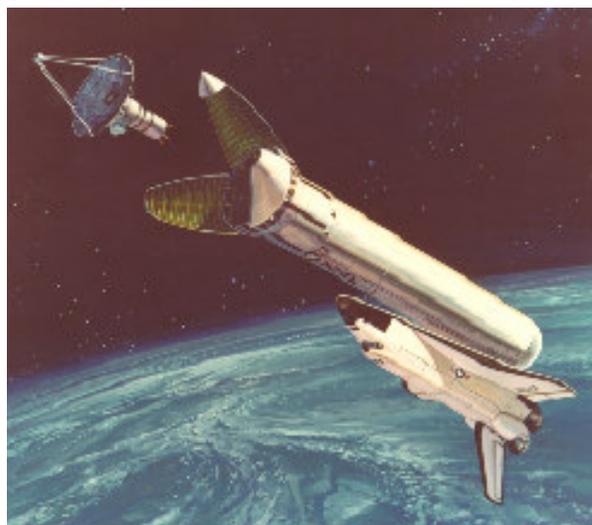
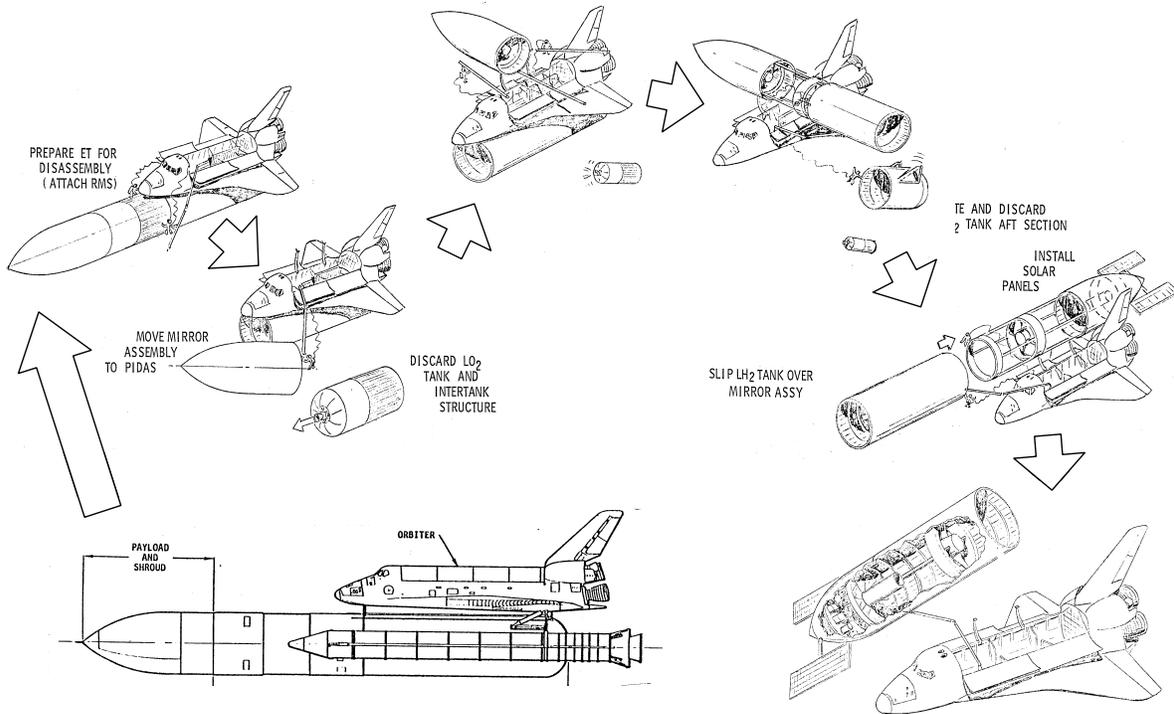


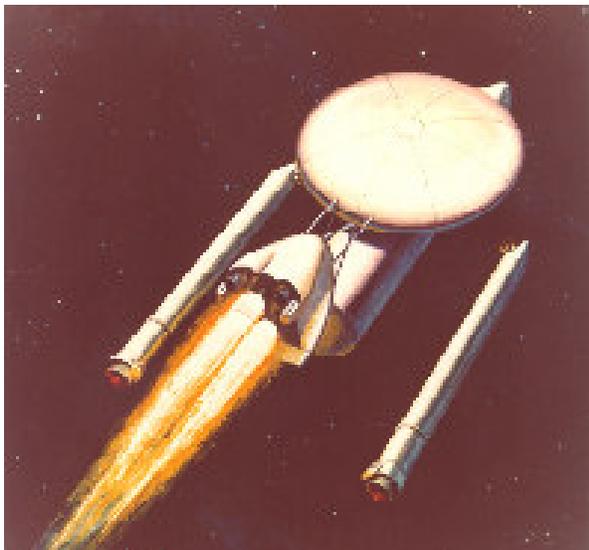
Figure 10. Large Diameter Low Density Payload Being Deployed From the Modified ET System. (Courtesy DARPA)



**Figure 11. Conceptual View Of How A 7.6 Meter Diameter Telescope Could Be Assembled From Elements Of A Modified External Tank. (Courtesy DARPA and Boeing)**

with a faired nose section since these stages were to be unmanned.

When we put all these elements together in truly heavy lift launch configurations, we got the ultimate in big launch systems. These systems included multiple LRBs, modified ETs, and propulsion modules. Using the liquid rocket boosters noted above, we were able to forecast delivery masses of up to 202,000 lb to LEO. With four of the liquid boosters, we found that we could get up to about 360,000 lb to LEO (Fig. 14).



**Figure 12. Lenticular Payload at Launch With a Lifting Recoverable Propulsion Module. (Courtesy Boeing)**

The SRBs weren't neglected, either. We developed augmenting thrusters to increase payload by what turned out to be about 9,880 pounds (Fig. 15).

#### **IV. Orbiter Conversion Options**

The orbiter was modified, on paper anyway, to provide additional capability in order to take advantage of the increased lift capability provided by the larger liquid rocket boosters developed during the "Shuttle Growth Study". We provided additional payload bay length and payload capacity (up to 75 feet and 100,000 lb). The "most favored" approach was to add a 15-foot barrel section just forward of the 1305 bulkhead. This was enabled the orbiter to carry the increased payload weight into the thrust structure. Then we added a new wing root and carry-through structure to handle the additional weight at landing, retaining the outboard section of the existing wing (Figs. 16 & 17). This gave us a landing capability with a 100,000 lb. payload at the same wing loading as in the basic orbiter. As an added benefit, this

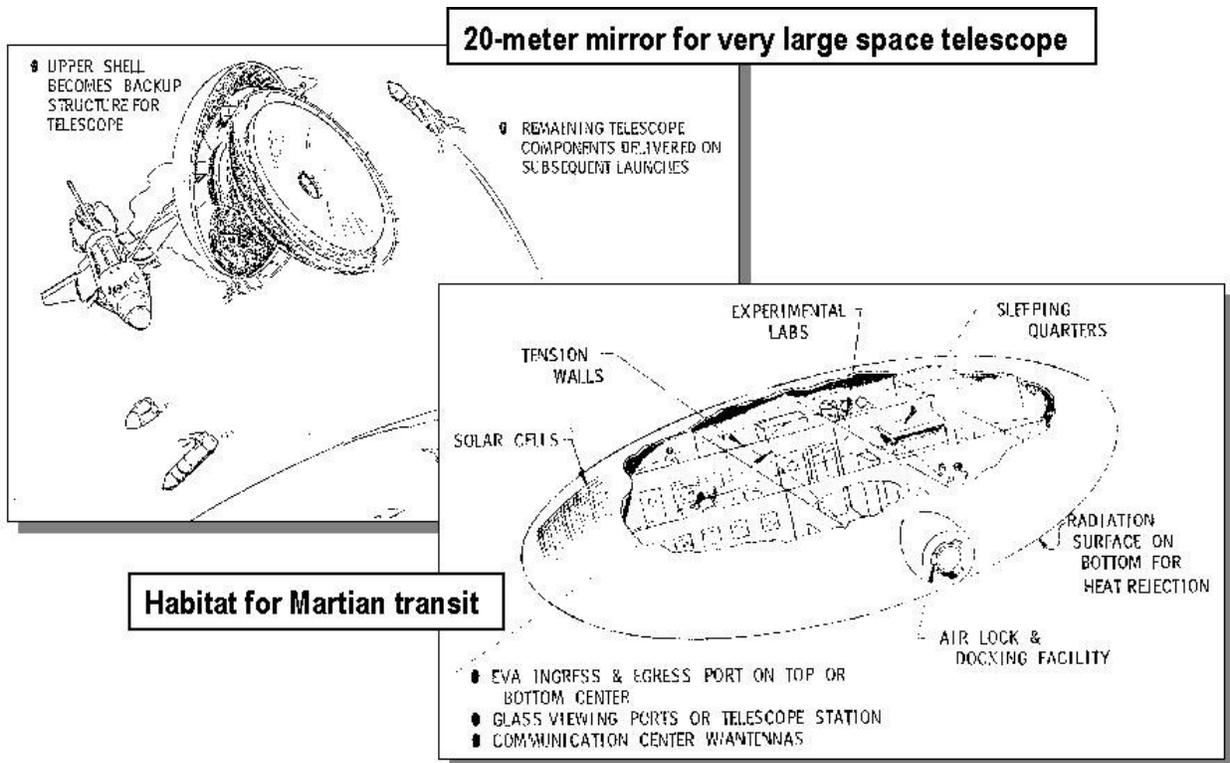


Figure 13. Lenticular Payload Carrier Presented Several Payload Opportunities. (Courtesy Boeing)

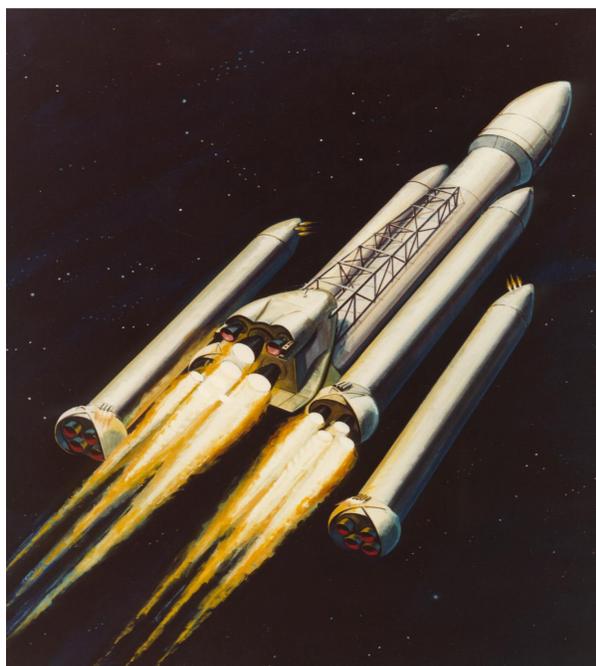


Figure 14. An Ultimate Launch System Using 4 LRBs, A Lifting Recovery Propulsion Module, and A Hammerhead External Tank Extension. (Courtesy NASA/MSFC and Boeing)

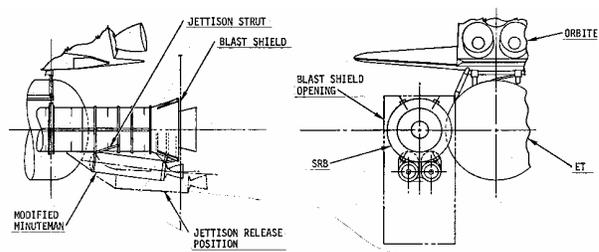


Figure 15. SRB Augmentation. (Courtesy Boeing)

resulted in a slightly higher L/D (4.67 vs. 4.34) at landing due to the relatively smaller base area compared to the wing area.

During a very early study of the mated Shuttle vehicle to determine how to reduce excessive orbiter wing loads, the elevon flipper doors were considered for conversion to direct lift control surfaces. These panels, on the upper surfaces of the wings, normally seal the upper elevon gap from the high temperatures of entry. They are normally slaved to the elevons to deflect with the latter. This study introduced actuators to deflect the panels during landing so as to directly control wing lift and runway approach flight paths without requiring orbiter rotation (Fig. 18). The Lockheed L-1011 and other aircraft of that era used them extensively While they were shown by wind tunnel

data to be effective, the system design was too far along the path to introduce this change.

Another conceptual design exercise led us to the definition a high-capacity passenger carrying capability to the orbiter. In that study, we defined a series of canisters that could carry from 68 to 74 passengers in a double deck arrangement (Fig. 19). There was no real definition of where they were to go except for going to a fictitious space base. This design pushed the center of gravity forward to the point where we had to change the baseline wing gloves with more canard-like surfaces to provide a more forward lifting surface area a more forward aerodynamic center.

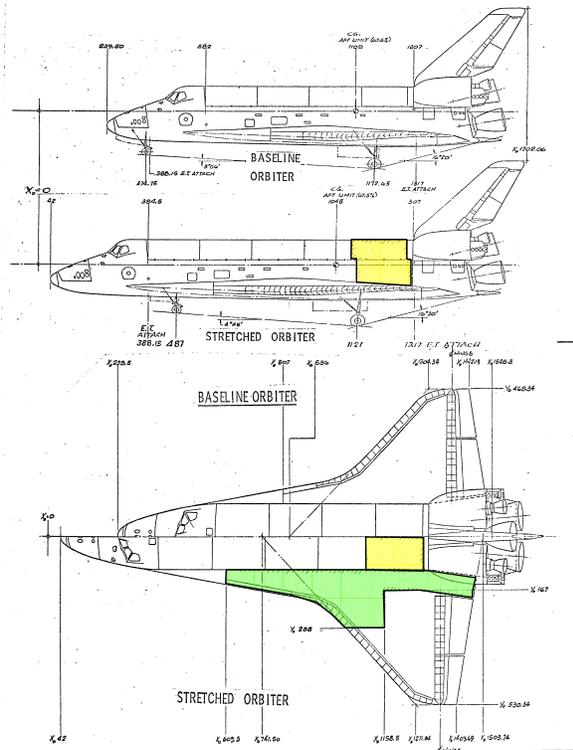


Figure 16. Stretched Orbiter - Plan View. (Courtesy Boeing)

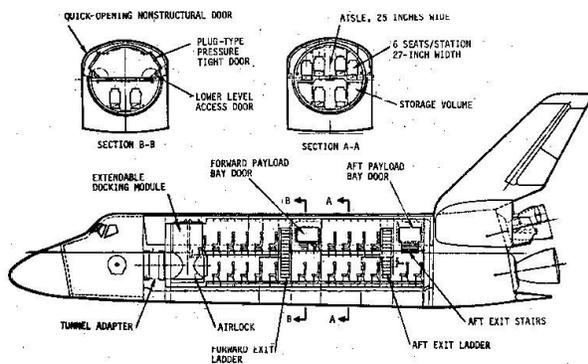


Figure 19. 74-Passenger Kit For Orbiter Payload Bay. (Courtesy Boeing)

- WING SPAN 1060.68 IN (88.39 FT)
- WING AREA 3315 FT<sup>2</sup>
- REFERENCE BODY LENGTH 1486 IN.

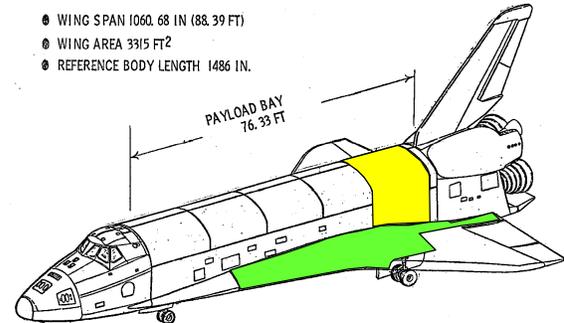


Figure 17. Stretched Orbiter - Isometric View. (Courtesy Boeing)

An undefined need for more payload bay volume inspired the thought that the lee side area above the payload bay (at entry angles of attack) could be used for an expanded bay. This resulted in what was called the “humpback” orbiter (Fig. 20). The wind shield area was faired into the higher moldline and whole faired into the

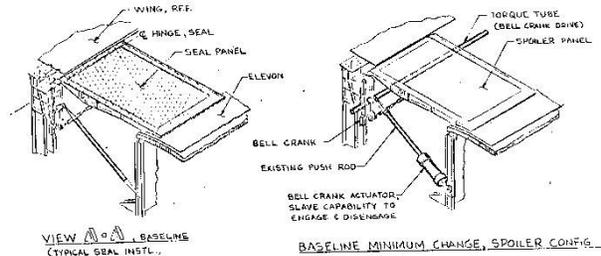
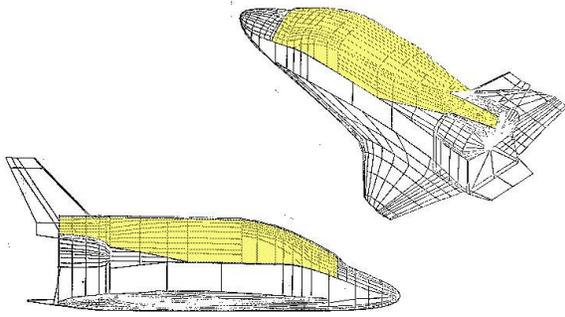


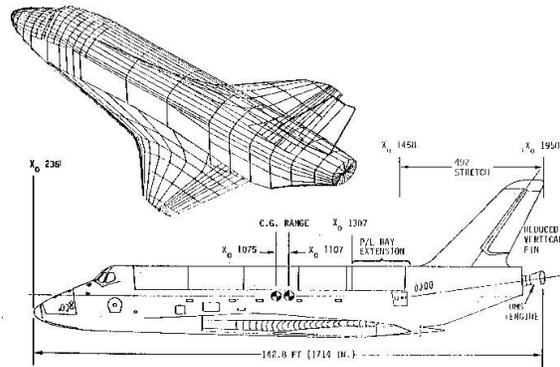
Figure 18. Flipper Doors Modified To Provide Direct Lift Control To Orbiter At Landing. (Courtesy Boeing)

vertical fin trailing edge. There was no change in the hypersonic aerodynamic characteristics at high angles of attack. However, there was no evaluation of the subsonic aerodynamic characteristics but it is likely that there some degradation of directional stability.

An engineless orbiter developed from a “challenge” by an individual at NASA/MSFC regarding the ability of the orbiter to evolve into an unpowered vehicle, something like the Russian Buran. This worked out very nicely, as seen in Fig. 21, by adding a payload bay segment at the aft end of the bay (as noted above for the stretched orbiter) and moving as much equipment into a new faired aft body as possible to compensate for the removal of the engines and thrust structure. The subsonic L/D increased to an estimated 6.02 as a result.



**Figure 20. A “Humpback” Orbiter Provided Additional Payload Volume Above The Payload Bay. (Courtesy Boeing)**



**Figure 21. Engineless Orbiter. (Courtesy Boeing)**

Finally, in the latter 1980s the projected an early edition of the Crew Emergency Rescue Vehicle (CERV) emerged. A large number of vehicle concepts were evaluated as candidates, including Apollo and some of its derivatives, the NASA/Langley HL-20, and the very early NASA/AF lifting bodies (the NASA HL-10 and M2F2, and the Air Force’s X-24A). A subscale version of the Shuttle orbiter was another candidate. The principal attractiveness of using the orbiter configuration was the detailed understanding of its aerodynamic performance.

## V. Alternate Developments Considered

Finally, we outlined options for developing a line of Shuttle-derived vehicles which could provide viable backups to the baseline Shuttle system. In the light of current events, these options may even more attractive.

We established ground rules that included payload commonality with the Shuttle fleet and a minimum impact on the Shuttle fleet due to their development.

The concepts and their development path included (see Fig. 22):

### *Orbiter Fuselage Derivatives:*

Modify from current orbiters	116,000 lb.
Refurbished OV101	116,000 lb.
MPTA w/simplified fuselage	166,000 lb.

### *Aft Fuselage Derivatives:*

Modify from current orbiters	150,000 lb.
New build plus new carrier	150,000 lb.
Refurbished OV101/MPTA plus carrier	145,000 lb.
Two-engine module plus carrier	75,000 lb.

### *External Tank Modifications:*

Propulsion/Avionics Module	157,000 lb.
In-line propulsion module	108,000 lb.
New reduced diameter tank	71,000 lb.

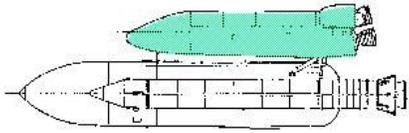
### *Orbiter Utilization:*

Unmanned flight kit for orbiter	65,000 lb.
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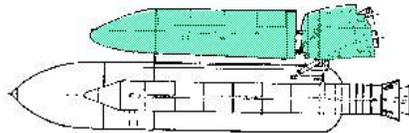
One can easily see from these wide-ranging studies of the possible variations and modifications of the Shuttle system elements that basic design is very flexible. Further development may be based on the basic elements and expanded by making use of the design history and the operational history gained during over twenty years of operations.

All of these options should be able to do the job for which they were intended, some more so than others. Indeed some may easily be summarily dismissed

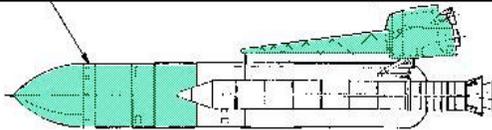
**Orbiter fuselage derivatives (expendable)**



**Aft fuselage derivatives (recoverable)**



**External tank modifications (recoverable)**



**Orbiter utilization (recoverable)**

**Figure 22. Most Promising Of The Shuttle Derivatives. (Courtesy Boeing)**

launched from the Earth’s surface with the possible exception of lunar manufactured propellants for the Mars missions. This will require both near term and far term launch systems. This paper has presented potential elements of these early systems, derived from well-defined existing systems. One such candidate is suggested for consideration in Fig. 24.

**VII. Closing Comments**

This paper is one of a casual series presented by the author over the last few years to capture some of the early work that was done in the early years of the space program. It is intended as a reminder to some of those who have been around for a while that many studies have been done, many of which may not be well publicized. This is a concern to many since that can incur duplication of effort. It is also a reflection that “Corporate Memory” of most if not all organizations, private and government, is quite short. It behooves all that this memory should be captured in a suitable form.

This paper is also directed to those newcomers in the aerospace industry who are just not aware of the extent of work that has been performed over the years. The paper presents only a small sample of that work - most of the other aerospace organizations were doing the same thing.

**VI. Recent Developments**

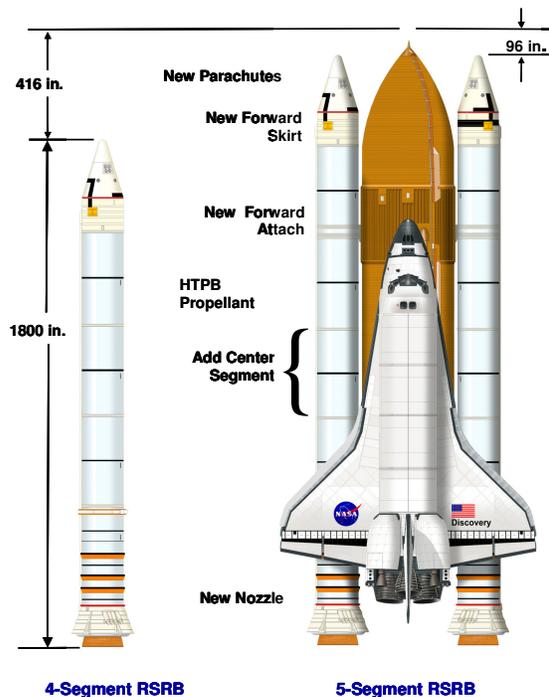
**A. Five-Segment Booster.**

It is pleasing to note that recently ATK Thiokol conducted a successful test firing of their new five-segment booster after a five and one half year development program. This booster was referenced in Fig. 6 of this paper as an “Improved SRM.” This new booster (Fig. 23) will provide for an additional 22-27,000 pounds of payload. Additionally, it will promote system safety by eliminating the needs for RTLS and ATL abort scenarios.

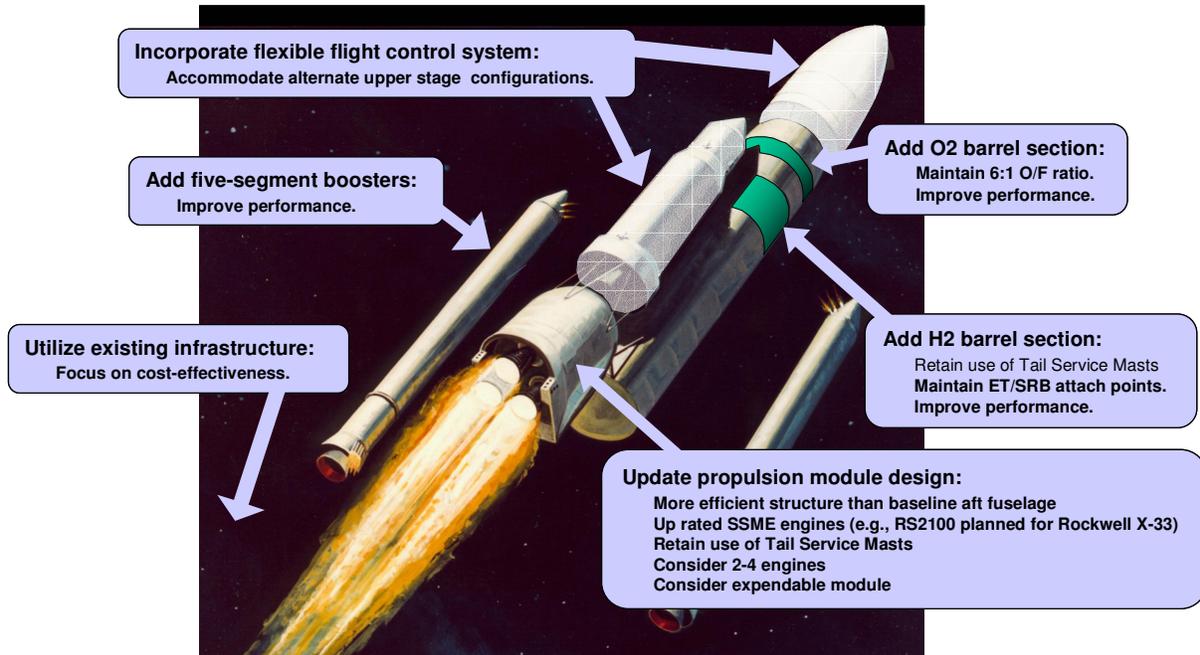
**B. Space Policy.**

The new Policy for Space Exploration presented by the President calls for launching missions to the Moon and to Mars. These missions are envisioned to be both robotic and manned with the first manned missions to the Moon to be initiated by 2015.

This constitutes an ambitious program but it interesting to note that all of the material must be



**Figure 23. Five-Segment Booster To Augment Space Shuttle Launch System Performance. (Courtesy ATK Thiokol)**



**Figure 24. Suggested Point Of Departure Launch System Concept For The President's New Space Exploration Program Based on Shuttle Derivatives and Near Term Updates. (Background Image Courtesy Boeing)**

## References

- <sup>1</sup> Jeffs, George, "The Space Shuttle Design and Construction," Rockwell International, second printing October 1979.
- <sup>2</sup> "Shuttle Growth Study," Rockwell International Report SD76-SA-0134-3, NASA Contract NAS8-32015, May 1977.
- <sup>3</sup> "Space Shuttle Vehicle Modification Program," AF SANSO/YAD Contract F04701-77-C-0087, December 1977.