The Shuttle Origin
or
The Making of a new Program
by
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Pre Lunar Landing Planning

- 2/61-10/68 Jim Webb didn’t want future plans—wanted to keep options open
- 3/69-9/70 Tom Paine never saw a future plan he didn’t like
- 1/64-10/68-Lots of lifting body work
- 10/68-early 70 NASA dreamed of ever increasing budgets, and planned accordingly

Initial Public Awareness
1969

- Agnew Study- with Bob Seamans, Tom Paine, Lee Dubridge
- Supported by NASA's ideas
  - 30 ft Diameter, 12 man Space Station
    - 2 in earth orbit, one in Lunar orbit
    - Lunar Base
  - Two stage fully recoverable Shuttle
    - 100-150 flights per year
  - SkyLab with 5 visits by Command Modules
  - Continue Saturn 1b and Saturn V production
  - Space tug for higher orbits than LEO
  - Nuclear stage for Moon and Mars
  - Mars program by 1983

Meanwhile, the Budget Crash

- Euphoria of 1968 followed by severe cuts
- Vietnam, Great Society budget deficits were causes, Nixon not a big supporter
- 1966 MSF budget=$3.8B, 1972=$1.7B
- Was there going to be a human space program at all?
- Mueller leaves in late 1969
- Paine leaves in late 70 (Low acting Admin.)
- Myers (1/70) and Fletcher (4/71)

NASA Strategy-1970

- Shuttle is first priority, because low cost to space will encourage all the Agnew Report items later
- Start 2 stage Shuttle Phase B, and
    - Cancel Apollo 18 and 19 and Saturn 1b and V
    - Cancel 2nd Skylab and CSM's
    - Cancel 30 ft. Space Stations
    - Don't start Space Tug
    - Don't start Nuclear Stage
    - Cancel Mars program

Industry down from 400,000 to 150,000

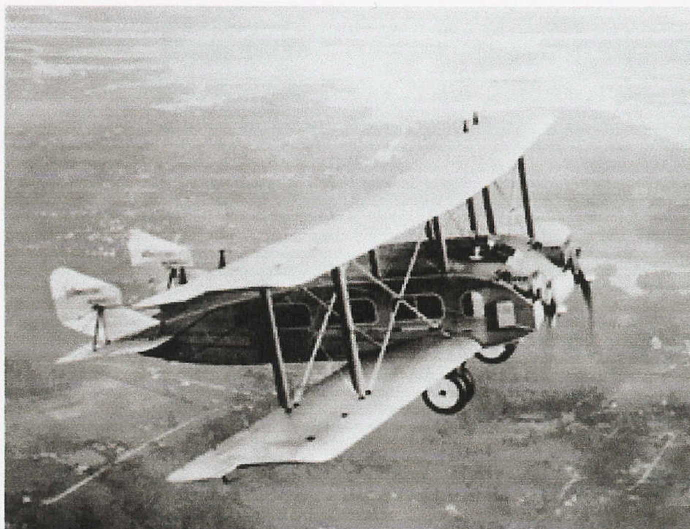
The Concept for a Shuttle

- Reusability equals low cost
  - “you wouldn’t fly to New York and throw away the airplane”
- Since R & D is higher, need many flights to beat ballistic systems
- The lower the R & D the less flights needed to beat ballistic systems
- If flights are many (because cost/flight is so low) a two stage, fully reusable system is right

The Technology Development
1950-1970

- Burnelli lifting body
- X-20 Dynasoar delta wing
- HL-10 Lifting body
- X-24A-Lifting body
- X-15-Winged, internal fuel
- X-15-Winged, internal and external fuel
- Navaho M=3 parallel tank separation

Burnelli Lifting Body



1921 - Long Island, NY
Burnelli RB-1 -- the first lifting-body reduced to practice.

1921 - RB-1

1st Lifting-Body aircraft ever built
U.S. Patent # 1,758,498
Filed: January 6, 1921
Issued: May 13, 1930

Evolution of the Shuttle
1969-1971

- Fully reusable two stage Straight wing, like an X-15
  - Internal fuel
  - Metal shingles (or unobtainium or some ablative)
  - 20000 lb. payload, due east
  - Payload bay 12X40?
  - 400 miles crossrange
  - 100 to 150 flights/year
  - $5 Million/flight in 1970 dollars

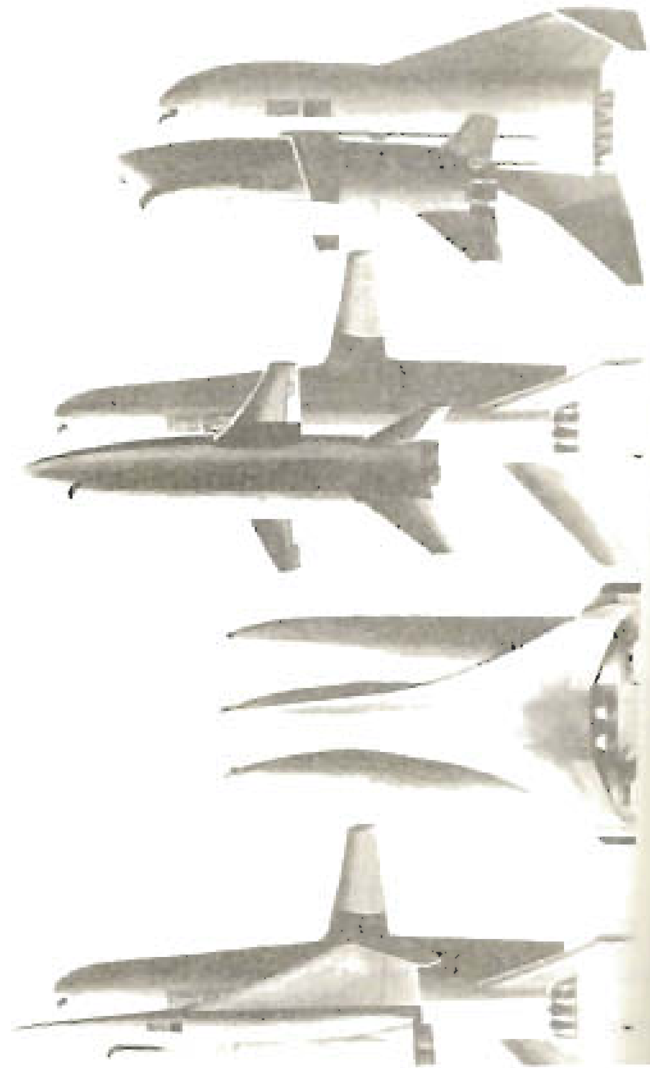
Meanwhile, the Mission Model

- When the Space Station, lunar base, etc. disappeared, we needed more payloads (50+/year)
  - Military agreed to put all payloads on Shuttle if we increased payload and designed for 1500 miles of crossrange, and met our cost/flight estimates.
  - Commercial agreed to carry all payloads on Shuttle (assumed we would develop a low cost upper stage and meet cost/flight estimates).
  - Science bought space servicing (i.e. Hubble) and a low cost reusable platform

Evolution of Requirements (mostly from Military Requirements)

- Payload increased to 40,000 lbs Polar
- Crossrange increased to 1500 miles
- Payload bay increased to 15 by 60
- Non ablative reusable thermal protection
- Two fully recoverable piloted stages
- Automatic checkout and 30 day turnaround

Chapter IV
Part 3



Lyndon B. Johnson Space Center

Evolution II

- Phase B showed Development of two stage fully recoverable Shuttle costs $14B for R&D
- Nixon says “Build any shuttle you want as long as it doesn’t cost more than $5B”
- OMB says “make it cost effective”
- NASA looked for alternatives with new Phase A
  - Single Stage to orbit
  - Trimese
  - X24B surrounded with tanks
  - External Orbiter tanks
  - Parallel or series booster

The Mathematica Study

- To convince OMB, Nixon and Congress
  - We hired Mathematica to do cost effectiveness study
- Results showed today's configuration best
  - Delta wing for crossrange
  - Weight increase for military payloads
  - 15 x 60 payload bay (15 for Space Station, 60 for military)
  - 40,000 lb. payload, polar
  - Parallel External throwaway monocoque tank
  - 2 Recoverable, abortable solids
  - Liftoff thrust augmentation with engines in Orbiter

Resulting Program

Nixon Start on Jan. 5, 1972

5 Orbiters

- Reusable Orbiter and engines, reusable solid cases, expendable fuel tank
- 40 to 50 flights per year
- $10M-$15M per flight in 1970$
- $5.2B+20% reserve for R & D in 1970$*
  - *As soon as Nixon left office, OMB forgot the 20% reserve
  - NASA Comptroller (pressed by OMB) didn't agree to 1970 base


US
STATES

Design Issues

- Straight vs Delta wing
  - Delta wing required for crossrange
- External vs internal tank(s)
  - External much lighter. Fuel transfer difficult
- **Thermal Insulation**
  - Ceramic tiles, carbon-carbon and blankets
- Solids or liquid booster
  - Solids looked more reliable and cheaper R&D
- Engine location and type
  - Start on ground safer, better performance
  - Staged combustion better performance
- Retractable turbojets
  - No--Depend on low L/D landings
- Series vs parallel boosters
  - Series heavy, less performance

Design Issues cont'd

- 2 Solids vs. 1 or 2 Liquid strapons
  - Two solids could be shipped by rail
  - Solids had a better reliability record
  - Solids could be recovered (industry studied pressure fed)
  - Designers thought they could turn off solids.
    - Later found they could not
- Thermal Insulation
  - Ceramic tiles, carbon carbon, and external insulation blankets (all new)
- High pressure staged combustion engine (new)
- Crew escape. (Only with complete structure)
- Operations Costs

Operations Costs

- Enormous confidence from the Apollo program
- Studies by American Airlines, IDA and the Aerospace Corporation nearly confirmed NASA operations costs
- NASA thought they had enough reliable, space based hardware in the industry to support quick turnaround, easy to maintain hardware
- NASA did not properly account for costs associated with:
  - **Post flight maintenance**
  - Assuring safety of flight in a hostile environment
  - Difficult cutting edge technology (Engine and Thermal)
  - FO/FO/FS
  - Cost tradeoffs between R & D and Operations

Operations Cost

- In 1970, $10M/flight price was based on same accounting system used for Apollo-hands on only, with a separate account for overhead.
- With $400M/year overhead, and inflation according to the consumers price index, cost per flight would be:

	1970	1981	2005
40 flts/year, no overhead	$10M	$23M	$50M
40 flts/year, include ovhd.	$20M	$45M	$101M
8 flts/yr, include overhead	$60M	$135M	$302M

Shuttle Performance

- The Shuttle has done everything it was designed to do. It has delivered Military, commercial, and scientific payloads to LEO and GEO, retrieved and replaced satellites, repaired spacecraft, and launched elements of the Space Station
- In the 80's, shuttle had 4% of launches, 41% of mass launched
- Shuttle R&D was within what Nixon and Fletcher agreed. ($5.2B +20% reserve in 1970$)
- Missed two key design issues (cold O rings and foam shedding)
- Missed operations costs. A two stage reusable system would have missed worse. Spacecraft are not "like an airplane".

Spacecraft are not like Airplanes

- Every flight is a "structural dive demo."
- No reusable space system gets millions of hours of stressed operation
- No reusable space system develops decades of evolutionary model improvement
- Every reusable system is exposed to enormous environmental variations
  - Thermal, vibration, pressure, Mach Number

So, for the next program

- Keep it simple.
- Don’t stretch the technology
- Use good margins of safety
- Keep it as small as possible
  - Carry as few passengers as possible
  - Carry people or cargo, not both
  - Keep requirements to a minimum
- Use as many past components and systems as have been proven reliable
- Design for operations
  - Easy access, one man can replace boxes, etc.
  - Keep a program design reserve to reduce Ops. costs


United States