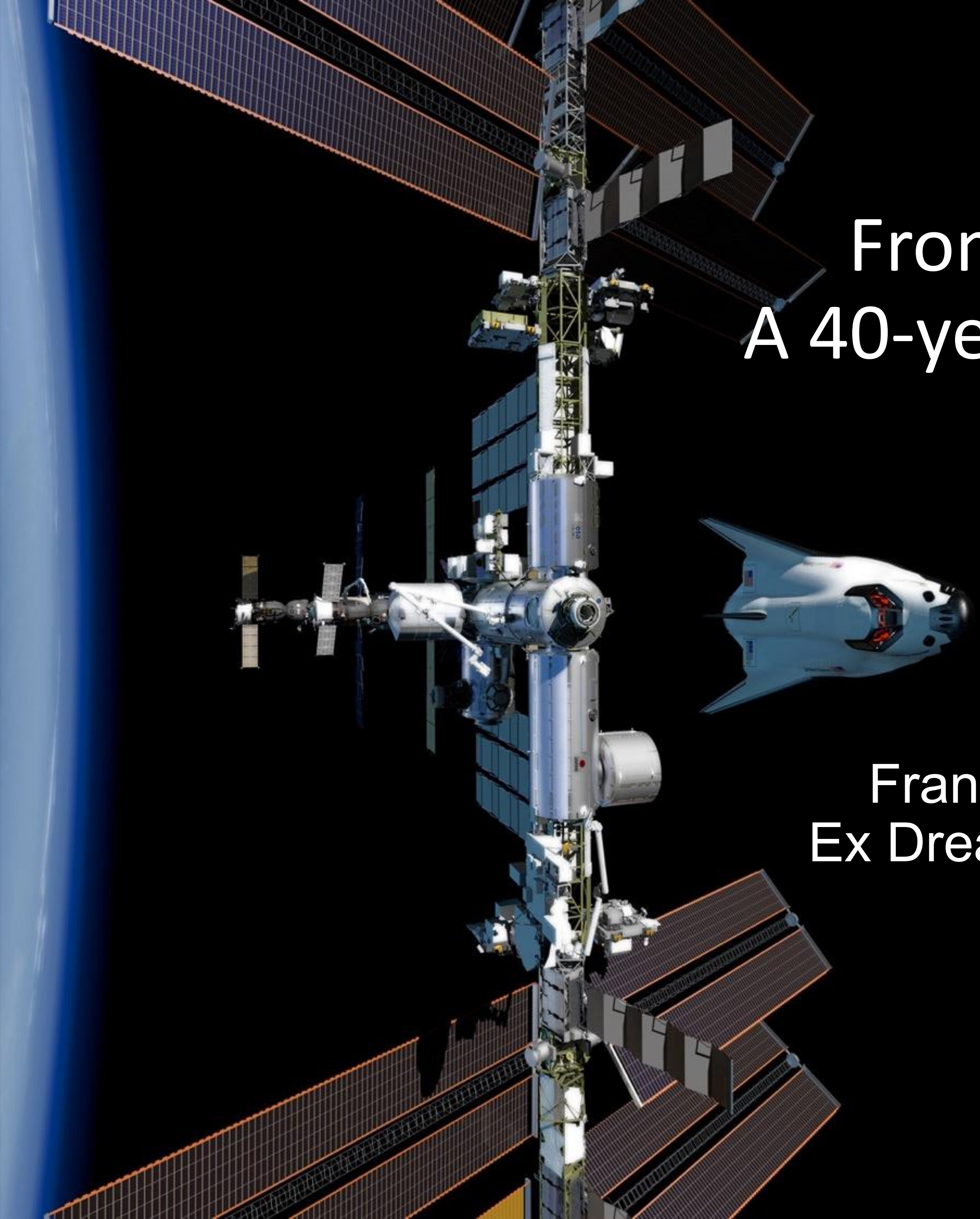


From the HL-20 to Dream Chaser: A 40-year Journey from Concept to Flight

Walt Engelund – NASA LaRC and HQ (ret)

Frank Taylor – SpaceDev / Sierra Nevada Space (ret)
Ex Dream Chaser PM/Chief Engineer/Sr Dir Technology

August 12, 2025

The Lifting Bodies (circa 1963 – 1975)

HL-10 at AFRC (circa 2025)

Indian Ocean, circa 1983

[redacted]

ANALYSIS OF THE COSMOS 1445 ENTRY VEHICLE (S)

by

Delma C. Freeman, Jr.
Head, Vehicle Analysis Branch

Distribution controlled by
Director, Governmental Affairs Division,
NASA Headquarters

REVIEWED FOR DECLASSIFICATION
UNDER E.O. 12958, AS AMENDED BY
E.O. 13292, SEC. 3.3 AND DETERMINED
UNCLASSIFIED.
AUTHORITY: NASA LARC

WARNING NOTICE –
Sensitive intelligence sources
and methods involved

UNCLASSIFIED

Classified by: LaRC Director

Declassify on: OADR

[redacted]

STUDY DEFINITION (U)

([redacted]) **Objective:** Analyze the Cosmos 1445 Entry Vehicle and develop possible mission scenarios based upon these assessments

([redacted]) **Approach:**

- Use available information and do a systems analysis to determine weights, volumes and payload potential
- Use existing lines to estimate vehicle aerodynamics and performance
- Use refined lines to build wind tunnel models and test over the entry speed range
- Use telemetry data and attempt to reconstruct the entry trajectory

~~WARNING NOTICE – Sensitive intelligence sources and methods involved~~

~~Classified by: LaRC Director~~
~~Declassify on: OADR~~

(U) ASSESSMENT TEAM

System Analysis:

Christopher I. Cruz
Ian O. MacConochie
James C. Young

Performance Analysis:

Richard W. Powell
Theodore A. Talay

Aerodynamics:

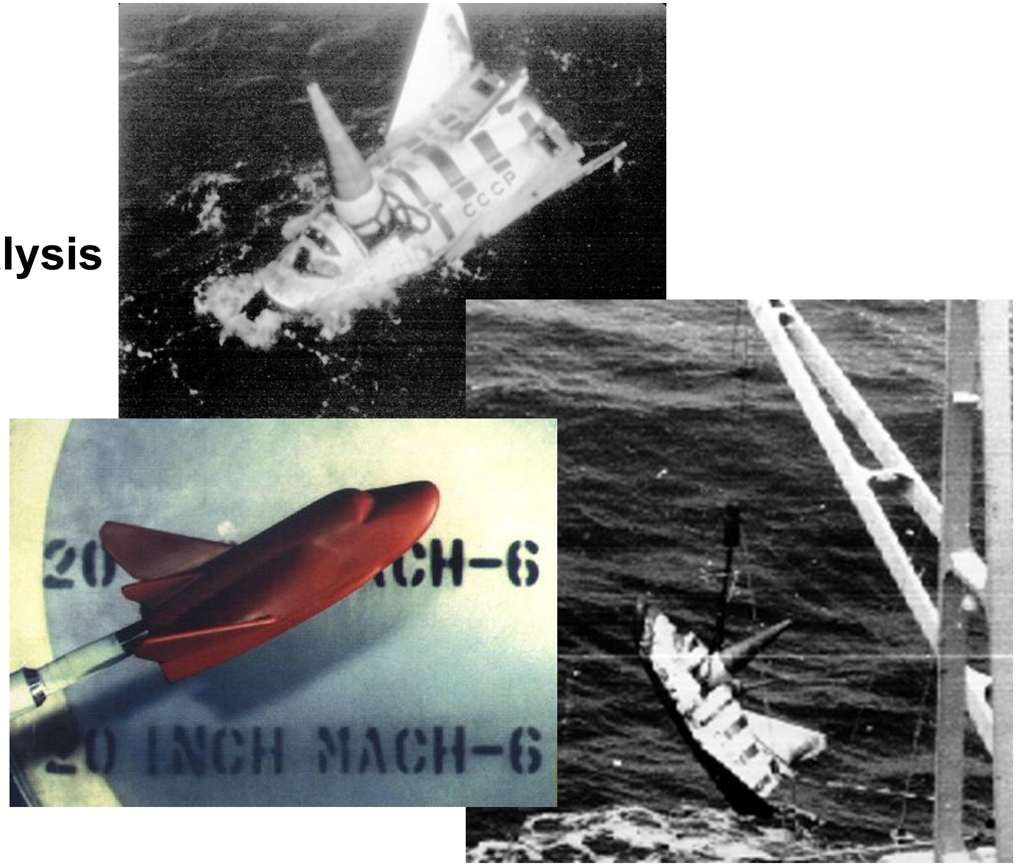
Delma C. Freeman, Jr.
Bernard Spencer, Jr.
William C. Woods

NASA BOR-4 VEHICLE ASSESSMENT -- 1983

- **Weight estimation**
  - — POST Trajectories
  - — Water displacement analysis
  - — Booster capabilities

- **Center of gravity estimate**
  - — Sling hanging analysis

- **Shape analysis**
  - — Photos used to produce wind tunnel models



Soviet spaceplane exhibited very good shape for entry.

SUMMARY MASS PROPERTIES (U)

Mass Property		Half Scale	Full Scale
([redacted]) Injected			
	wt, lb	3425	24,684
	c.g., %	60.0	60.0
([redacted]) Entry			
	wt, lb	2694	10,010
	c.g., %	54.0	55.0
	w/s, lb/ft^2	45.8	43.4
([redacted]) Landing			
	wt, lb	2400*	9,987
	c.g., %	55.4*	55.0

*Less parachute and parachute hatch

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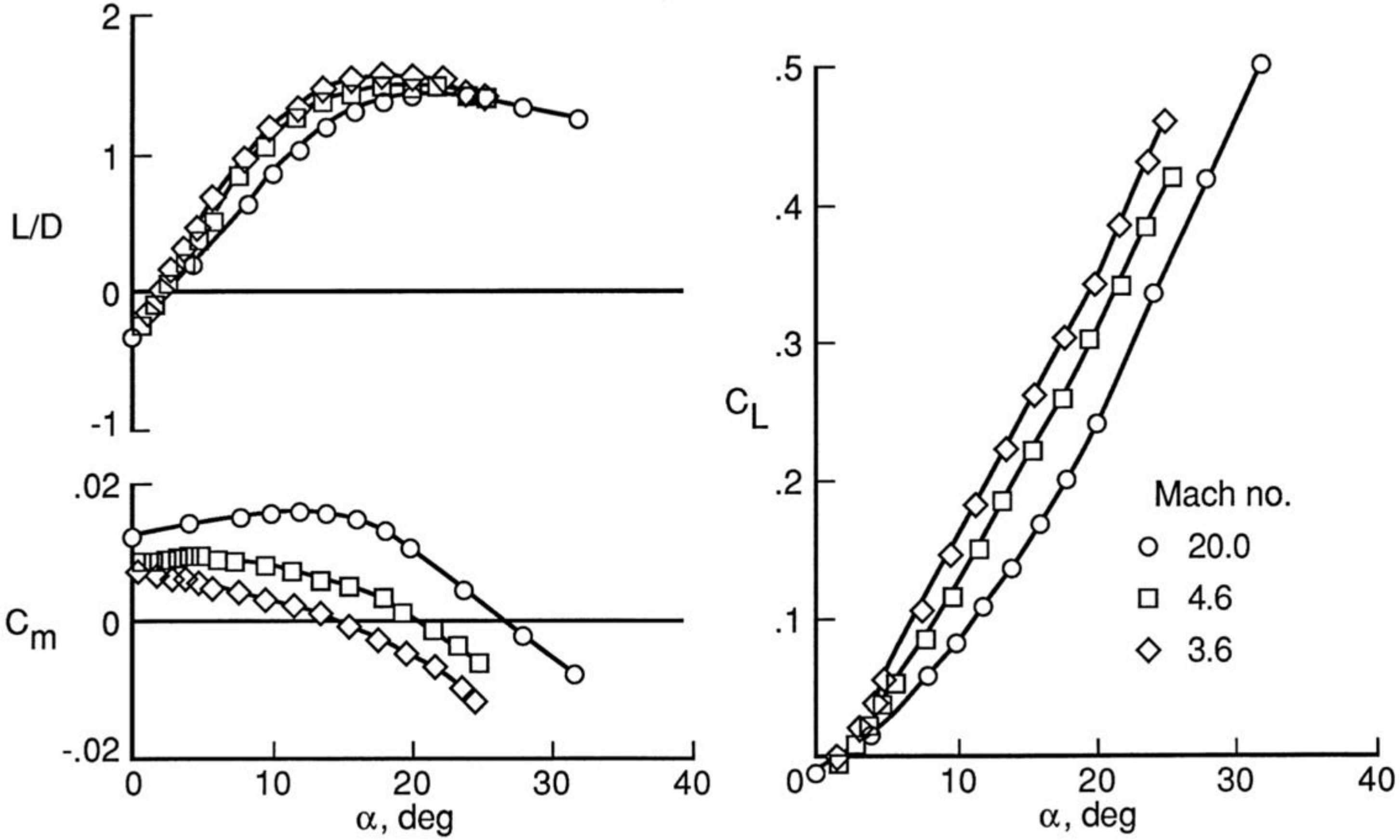
FACILITY DESCRIPTION (U)

Subsonic	
$M = 0.6$ to 0.9	Diffuser Flow Apparatus
$RN_L \cong 1.75 \times 10^6$	(NTF Model Tunnel)
Supersonic	
$M = 1.6$ to 4.63	Unitary Test Sections I & II
$RN_L \cong 2 \times 10^6$	
Hypersonic	
$M = 20$	LaRC 20 Inch Helium Tunnel
$RN_L \cong 3.4 \times 10^6$	

HYPERSONIC/HIGH SUPERSONIC LONGITUDINAL CHARACTERISTICS (U)

Moment ref = 0.54 L



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and methods involved

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SUMMARY OF SYSTEM ANALYSIS OF COSMOS 1445 SPACECRAFT (S)

- ([redacted]) • Unmanned, too small (~13 ft length)
- ([redacted]) • Vehicle weighs approximately 2,700 lb
- ([redacted]) • Maximum payload of 300 lb
- ([redacted]) • Maximum insertion weight of 3,400 lb
- ([redacted]) • Test vehicle not configured to fly below Mach 2
- ([redacted]) • Passive stable above Mach 2
- ([redacted]) • Maximum aerodynamic cross range of 1,100 n.mi.
- ([redacted]) • From an initial orbit of 123 n.mi.
    - Maximum plane change of 4 degrees

      or
    - Maximum orbital altitude of 500 n.mi.

~~WARNING NOTICE – Sensitive intelligence sources and methods involved~~

Classified by: LaRC Director

Declassify on: OADR

SUMMARY OF ANALYSIS OF FULL-SCALE VEHICLE (U)

([redacted]) • Two-man spacecraft (assumed) ~26 ft length

([redacted]) • Vehicle weighs approximately 9,300 lb

([redacted]) • Maximum payload weight of 3,000 lb

([redacted]) • Insertion weight of 28,000 lb

([redacted]) • Maximum aerodynamic cross range of 1,300 n.mi.

([redacted]) • With maximum propellant (3 tanks) loading and 3,000 lb payload

- A maximum plane change of 13°

  or

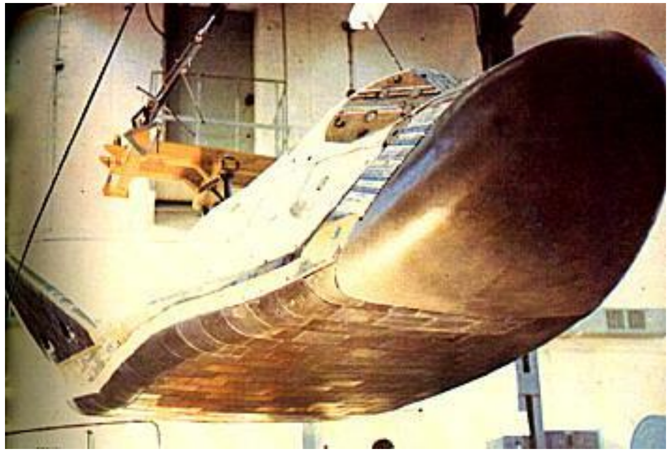
- A maximum altitude of 1,700 n.mi. from an initial orbit of 123 n.mi.

Spiral and BOR-4 History

- Russian Spiral OS – (mid 1960's – early 1970's)
  - 3 main components
  - Reusable hypersonic air-breathing launch aircraft
  - Expendable 2 stage rocket
  - Orbital spaceplane

Spiral OS

- BOR subscale flight tests series (1982-84)
  - Unmanned orbital rocket plane
  - Hypersonic aero and heat shield materials testing for Soviet Buran Space Shuttle design
  - 4 successful flight tests
  - Intelligence photos taken by Australians during recovery operations



BOR-4

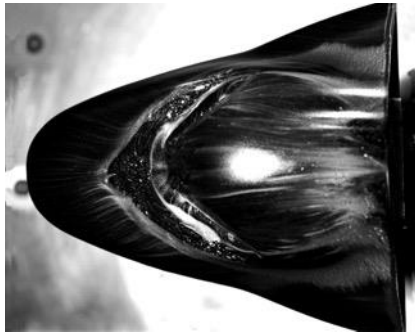
HL-20 LIFTING BODY BACKGROUND

- 1983-86 -- Investigation of Soviet spaceplane; In-house design
- 1986-88 -- Looked at shape as Crew Emergency Rescue Vehicle (CERV & ACRV) & two-way transport (STAR)
- 1988-89 -- Personnel Launch System (PLS) work begun
  - In-house vehicle maturation continuing
- 1989-90 -- Contract with Rockwell for 10-person HL-20/PLS
- 1990-91 -- Further In-house HL-20 studies -- Full scale mockup
- 1991-92 -- HL-20 Skunk Works Study
- 1992 -- Goldin HL-20/PLS cost exercise
- 1993 -- Access to Space - Option 2 -- HL-42
- 1992-2000 -- Utilization of Rockwell & Skunk Works results in numerous studies/reviews

HL-20 LIFTING BODY STUDIES

- HL-20 versions studied
  - 4 to 10 people
  - Station rotation, CERV/ACRV, servicer, OMV, lunar crew rotation, cargo, technology testbed
  - Boosters from Atlas IIAS to Titan III and NLS
- Over 15-year in-house effort; two major contractor studies
- Extensive full-range wind tunnel, CFD data bases
- Autoland/abort studies, flight simulators, full scale mockup
- Costed numerous times; HQ reviewed
- Briefed to two NASA administrators (Truly, Goldin)

Aerodynamics

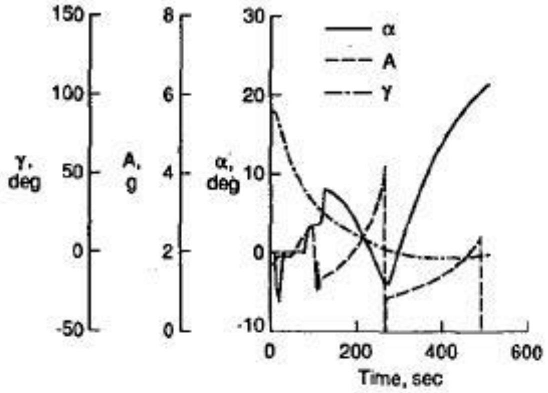


- **Database Development – (M = 0.1 - 20)**
  - Longitudinally and laterallly stable across entire range – (M = 0.3 - 20)
  - Neutral directionally stability – (M = 2.5-3.5)
  - L/D Max – (Hypersonic = 1.4 to Subsonic = 4.3)
  - Control surface deflections at L/D max
    - 10 deg. – subsonic
    - 0 deg. – (M = 0.6-0.9)
    - 3 deg – transonic
    - 0 deg. – (M = 2-20)
  - Work to improve low subsonic – (M < 0.3)
    - HL-20 A-D testing – (OML shape changes)

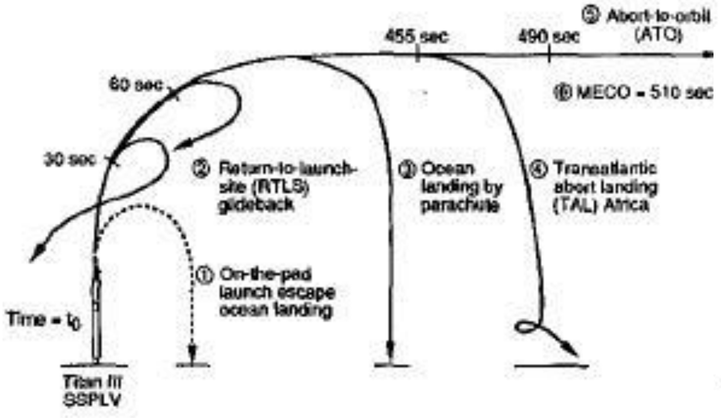
Test facility	Mach number	Number of runs	Type of test
Full-scale Tunnel	0.1	130	Force and moment
Low-Turbulence Pressure Tunnel	0.2	139	Force and moment
7×10 High-speed Tunnel	0.348	184	Force and moment
CALSPAN 8-ft Transonic Tunnel	0.6–1.2	244	Force and moment
Unitary Plan Wind Tunnel	1.6–4.5	412	Force and moment
20-in. *M*=6 Hypersonic Tunnel	6	126	Force and moment thermal mapping visualization
CF_4 *M*=6 Hypersonic Tunnel	6	73	Force and moment thermal mapping visualization
31-in. *M*=10 Hypersonic Tunnel	10	83	Force and moment thermal mapping visualization
22-in. *M*=20 Hypersonic Tunnel	20	26	Force and moment
MSFC 14-in. Trisonic Tunnel	1.5–4.5	28	Force and moment

HL-20 at NASA LaRC

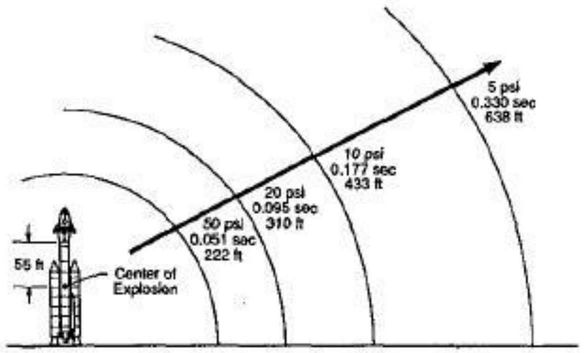
Trajectory Analysis



Ascent Profiles

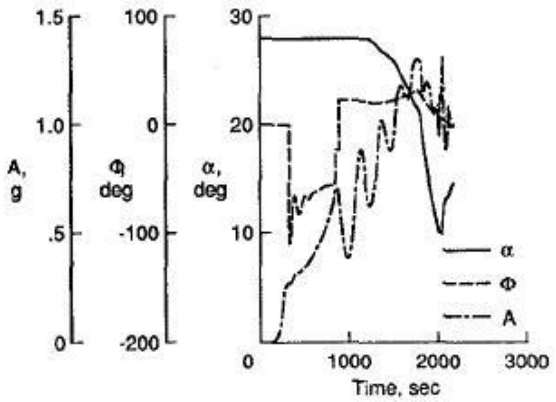


Abort Modes



Explosion Overpressures

- Ascent, abort, entry assessment studies for PLS – (using POST)
  - Titan III launch to ISS – (28 deg. incl, 220 nmi.)
  - Abort scenarios examined – (On-the-pad, return-to-launch, ocean landing with parachute, transatlantic abort, abort-to-orbit)
  - Entry analysis using 5 landing sites (KSC, Edwards, Hawaii, Guam, Dakar) assuming daylight landing
- Results provided
  - Time intervals for mission and abort success
  - Daily landing opportunities – (Entry to primary/sec. sites from ISS)



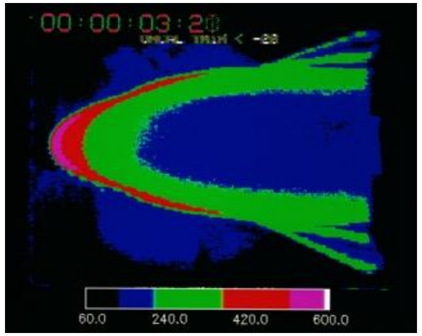
Entry Profiles into KSC

Thermal Protection System

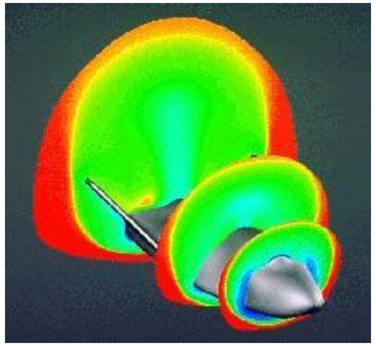
- TPS selection based on the following
  - Protect vehicle structure and crew
  - Reusable with minimal maintenance
  - Durable within space and ground environments
  - Utilize near-term technology

- Design driven by peak heating rates & total heat load – (entry trajectory)
- MINIVER Analysis validated and used with experimental and CFD results
- Time history results used in POST

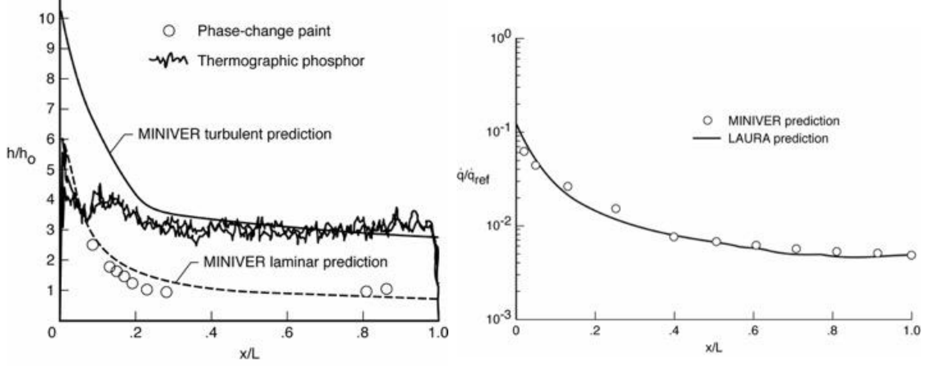
- Materials selected
  - Advanced Carbon-Carbon – (ACC)
  - High-temperature Reusable Surface Insulation – (HRSI)
  - Advanced Flexible Reusable Surface Insulation – (AFRSI)



Experimental

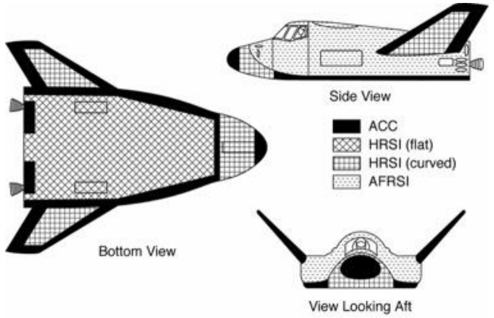


3-D CFD

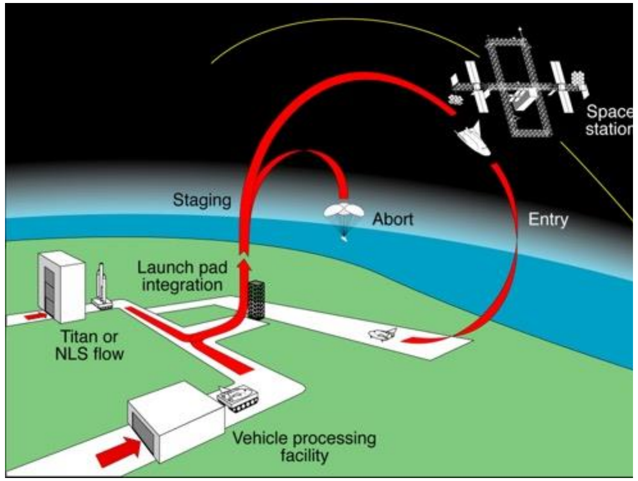


Analysis comparisons to Experiment And CFD

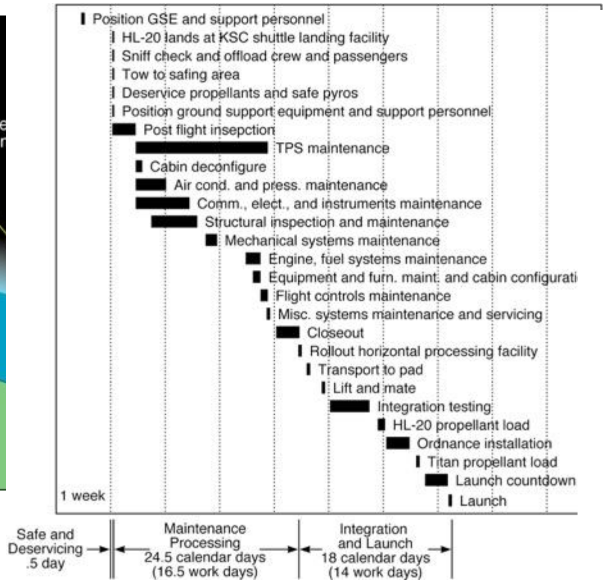
TPS Layout →



Operations and Support



PLS Operations Scenario



PLS Processing (31 work days)

Systems	Vehicle processing time, manhours: Shuttle orbiter	Estimated HL-20 lifting body	Decrease for HL-20 compared with shuttle
Quality	1,020	76	944
Integration	186	60	126
Purge, vent & drain	656	164	492
Mechanisms	1,611	86	1,525—No bay
Structures/handling	2,932	460	2,472
Thermal protection system	10,636	976	9,660—Smaller
Main propulsion/SSME	7,012	0	7,012—No SSME
OMS/RCS	1,288	1,288	0
Fuel cell/PRSD	248	248	0
Auxiliary power unit	416	0	416—No APU
Launch accessories	90	32	58
Pryotechnics	292	38	260
Hydraulics	1,045	0	1,045—No hyd
ECLSS	1,724	700	1,024—NOWCS
Flight crew	208	112	96
GN&C	780	176	604
Digital	226	88	138
Communications	135	52	83
Instrumentation	76	32	44
Electric power distribution	224	80	144
Software	80	40	40
Cargo bay	3,336	0	3,336—No bay
Total	34,131	4,708	29,519

[a]SSME: Space Shuttle Main Engine; PRSD: Power Reactant Storage and Distribution; hyd: hydraulics; ECLSS: Environmental Control and Life Support System; and WCS: Waste Collection System.

Hands-on Manpower Requirements

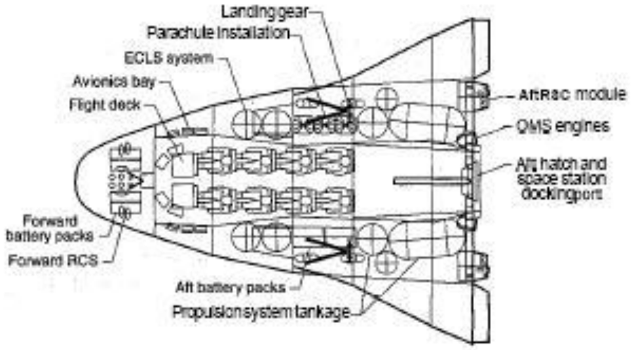
- Studies of landing, launch, mission operations
- Support defined by manpower, staffing, facilities, GSE, maintenance, turnaround processing time
- DRM – (to and from KSC, 3 day crew rotation)

	MYR	Headcount: Total	Eng	Tech	Mang
Nonflight	10.47	86			
All flight	7.50	60			
Flight specific	16.99	206	144	48	13
Develop operations process requirements[a]					
Establish flight groundrules and constraints[a]					
Develop mission initialization plans and schedules	1.50	26	18	6	2
Develop initial flight design and data	3.08	31	22	7	2
Prepare crew activity plan	0.38	6	4	1	0
Prepare mission products & documentation	3.38	34	24	8	2
Perform prelaunch real-time support	0.25	4	3	1	0
Perform crew and flight controller training	8.13	72	50	17	5
Real time support/simulations	0.27	33	23	8	2
Total mission operations staff		352			

[a]Functions occur infrequently, manpower requirements assumed handled by other functions.

Operations Staffing

Subsystems



Subsystem Layout

Subsystem	Rockwell baseline	Lockheed baseline
Aerosurface actuators	EMA	Same
Landing gear	Figher-type	F-5E modified
OMS/RCS	JP4/H_2O_2	MMH/N_2O_4
Avionics		
Processing system	ASCM/MDM	Same
GN&C	GPS/INS	Same
Communications	Telemetry, voice, air traffic control	Same
Vehicle health monitoring	Dual redundant processors	Vehicle management system
Software lines of code	290 k	206 k
ECLS	RCRS	Lithium/hydroxide
Personnel accommodations	Seats/ladder; no head or galley	Same
Power supply	Silver/zinc batteries	Same
Power distribution	28 Vdc	Same
Thermal control	Heat sink	Same
Adapter	Large (ALS)/heavy	Small (Titan III)/light
LES	Six solid boosters	Four solid boosters

Baseline Selections

Component	Rockwell Weight, lb		Lockheed Weight, lb	
Wing group	1869		1782	
Center fin	69		69	
Body group	3502		3502	
Thermal protection	2124		2166	
Landing gear	1161		927	
Propulsion	1366		976	
Prime power	2880		2695	
Electrical conversion and distribution	1226		1170	
Actuators	172		268	
Avionics	1337		978	
ECLS	2070		1618	
Crew accommodations	1434		1180	
Recovery and auxiliary	1961		1839	
HL-20 dry weight	21,173		19,170	
Personnel and provisions	2415		1953	
Fluids and residuals	727		318	
HL-20 landed weight	24,315		21,441	
Consumables	5038		4045	
HL-20 launch weight	29,353		25,486	
Adapter/LES	10,348	(Titan IV)	6699	(Titan III)
HL-20/adapter launch weight	39,701		32,185	

Mass Properties

- Subsystems developed to maximize efficiency and minimize costs
- Both concepts using current technology with flight heritage – (Shuttle)
- No subsystem technology breakthroughs required for PLS concept
- Both designs focused on ease of maintenance
- Similar selections by both designs and subsequent results gives creditability to PLS concept

HL-20 Mockup Construction

- Construction by NC State through NASA Grant - (1990)
- Built for Systems and Human Factors evaluation
- 48 cross sections created from 90000 data points
- Generic structure created using layup technique of epoxy with dacron cloth within polystyrene molds – (up to 5 plies)
- Plywood used in bulkheads, longerons and flooring
- Landing gear from Piper Navajo using aluminum shafts
- Interior – (23 ft. length, varying 4 to 6 ft. height, 560 ft^3 volume)

Human Factors

- Study goals
  - Anthropometry – human size related to job function ability
  - Internal / Equipment layout / Crew seating
  - Crew ingress and egress with Shuttle suits
  - Acceptability – (2 hr. time intervals)

- Full scale mockup constructed by NC State
- 35 person study – (10 person crew teams)
  - Horizontal, vertical, and pilot view testing
  - 5%-95% size for Japanese females / American males
  - 4’ 9” to 6’ 3” height and 116 to 235 lbs.
- Results
  - Safe design for ingress/egress regardless of vehicle pos.
  - Reasonable acceptability for full crew – (volume, proximity)
  - Pilots field of view deficient – (possible nose reshaping)
  - Redesign cockpit – (5’ 7” max, more usable volume)

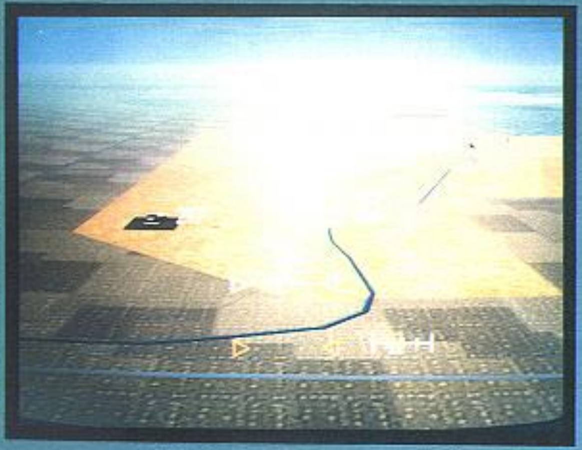
Vertical Position

HL-20 LANDING SIMULATION

LANDING SIMULATION PILOTS

Name/Affiliation

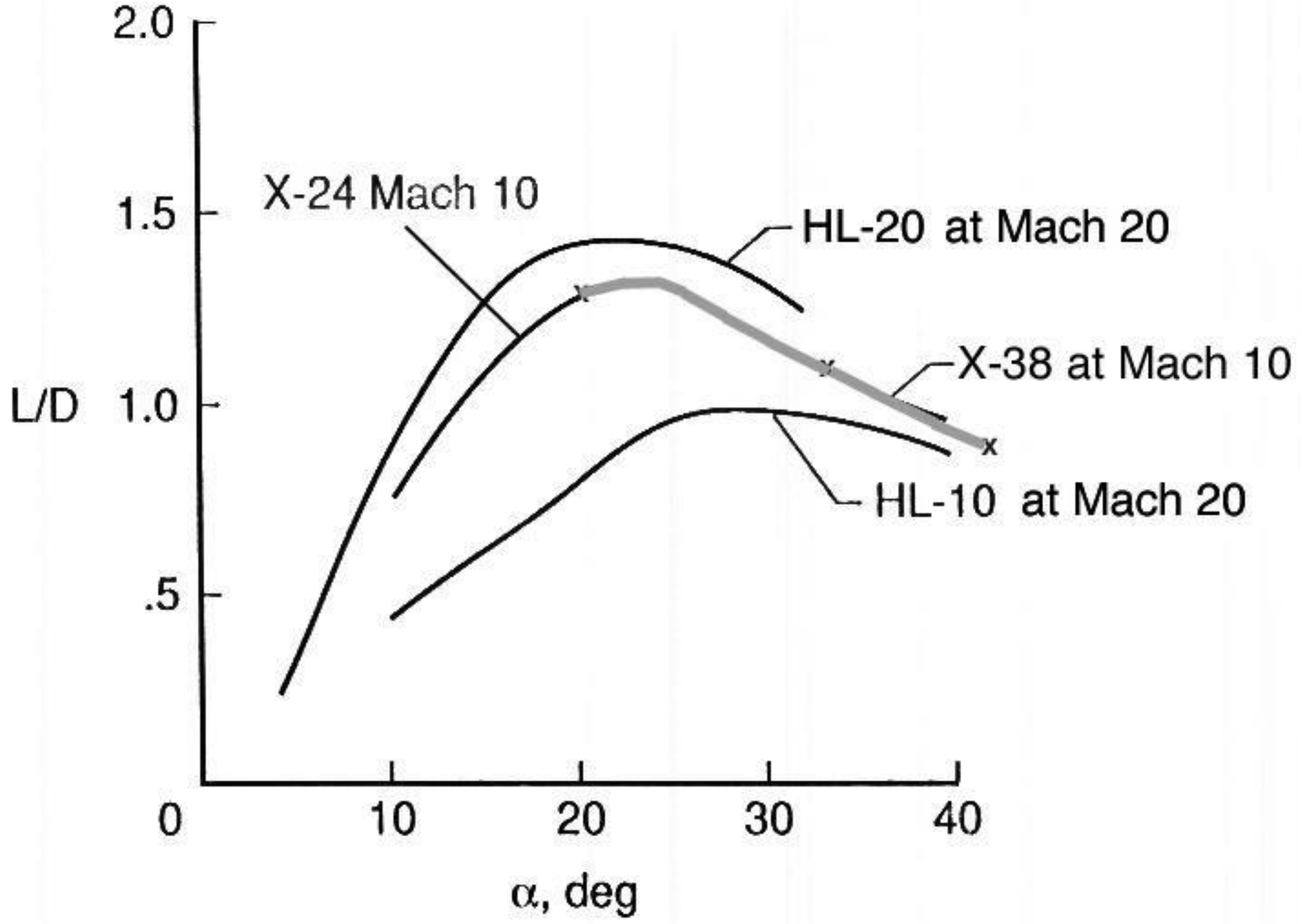
Bob Cabana/JSC-Astronaut
Bill Dana/DFRC-Lifting Body Pilot
Mike Foale/JSC Astronaut
Bob Harper/CALSPAN-Flying Qualities Expert
Steve Ishmael/DFRC-Test Pilot
Bill Lenoir/Headquarters AA for Space Flight
Rob Rivers/LaRC-Former STA Instructor Pilot
Richard Truly-Astronaut/STS-2 and STS-8
John Young/JSC-Astronaut/Commander STS-1



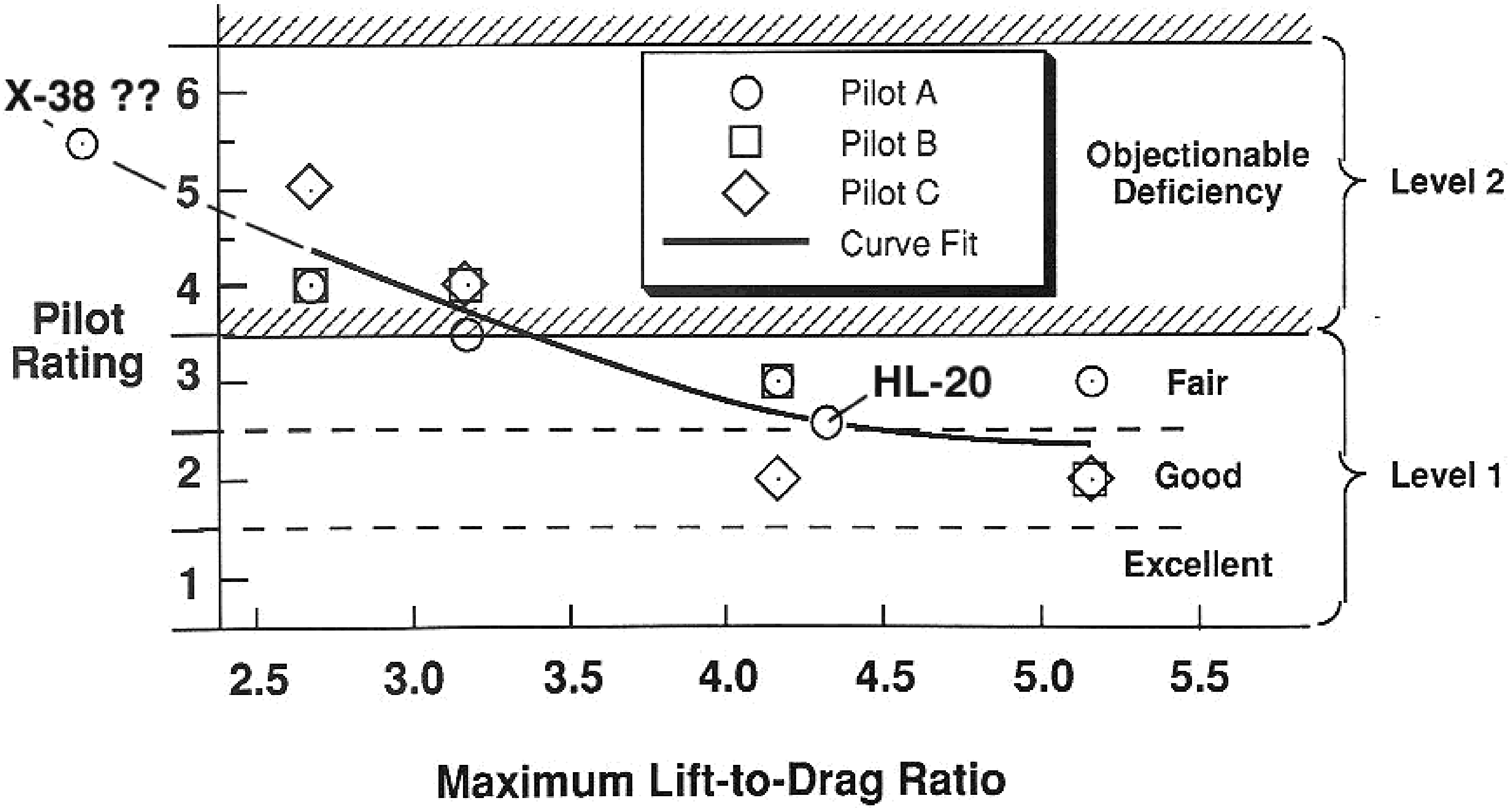
MANUAL LANDING CAPABILITIES

- Crosswind up to 30 knots demonstrated
- $\pm$ 25% off-nominal energy approaches demonstrated
- Consistent sink rates below 5 ft/sec
- Consistent touchdowns within 20 knots
- Good flying qualities (HQR Level 1)

COMPARISON OF HL-20, X-24 AND HL-10 & X-38 HYPERSONIC L/D RATIOS



Effect of Lift-to-Drag on Pilot Rating



SpaceDev Partnership (2005)

- Edwards AFRL meeting – (George Harting, 7/26/05)
  - Hybrid rocket propulsion – (history, technology issues)
  - Potential for C&I Proposal
  - Centennial Challenge
  - SpaceDev Dreamchaser project – (X-34, NASA ARC)
  - NASA Ames recommends HL-20 concept
  - G. Harding makes contact with SpaceDev
- First SpaceDev Telecon - (8/10/05)
- Several telecons on HL-20 – (9/05)
- Original Commercial Orbital Transportation Services solicitation released – (10/28/05)
- Official visit, flight simulator/Hangar Mockup tours, and presentation to Directorate – (11/15/05)
- SACD Letter of Commitment signed – (12/6/05)

National Aeronautics and
Space Administration

Langley Research Center
100 NASA Road
Hampton, VA 23681-2199

December 6, 2005

Reply to Attn of: 449

Jim Benson, CEO
SpaceDev
13855 Stowe Drive
Poway, CA 92064

Subject: Letter of Commitment for Support in Commercial Orbital Transportation Services (COTS) Space Flight Demonstrations Solicitation

The System Analysis and Concepts Directorate (SACD) of NASA Langley Research Center (LaRC), with support from the Research and Technology Directorate (RTD) and Systems Engineering Directorate (SED), is pleased to provide technical information and data in support of the development of a competitive proposal for the NASA solicitation entitled, "Commercial Orbital Transportation Services (COTS) Space Flight Demonstrations."

Based on your objectives and plans for COTS flight demonstrations, we were very pleased with your proposed use of the NASA LaRC-developed HL-20 space vehicle concept with a planned development of a SpaceDev commercial space transportation system using hybrid rocket propulsion. After over a decade of research and development at NASA LaRC, the Exploration Concepts Branch, with other important LaRC organizations, has the requisite knowledge and experience, analysis capabilities, and critical data of the HL-20 system needed for your proposed commercial space transportation system. We are pleased to be a member of the SpaceDev team on this proposal.

In addition, upon successful COTS selection, NASA LaRC/SACD will enter into a NASA multi-center Space Act Agreement with SpaceDev for the purpose of providing overall NASA technical management, systems analysis support, and relevant discipline expertise from SACD, RTD and SED. This letter serves as a commitment on behalf of NASA LaRC/SACD to provide expertise, analysis and personnel support in accordance with the conditions of the COTS solicitation and proposed NASA Space Act Agreement.

Attachment A lists the critical NASA LaRC personnel in support of this activity. The Space Act Agreement will define their actual time commitment depending upon the details of the activity.

Dr. Ajay Kumar, Director
Systems Analysis and Concepts
Directorate

Enclosure

Why was SpaceDev Interested in HL-20

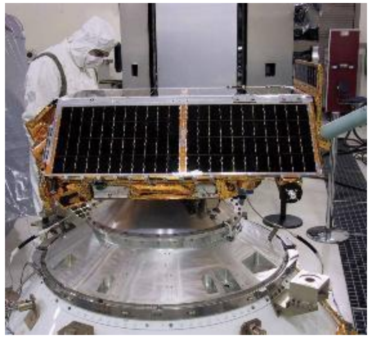
Microsatellites

CHIPSat (Cosmic Hot Interstellar Plasma Spectrometer Satellite)

Hybrid Propulsion

Hybrid Rocket Propulsion System: *<u>SpaceShipOne 2004</u>*

SpaceDev Team 6/2004



SpaceDev CHIPSat 2003

SpaceDev SS1 Flight Tests Sept + Oct 2004

SpaceDev SS1 Motor Firing 7/2003

SpaceDev /Starsys Merge
10/26/2005

SNC Acquires MicroSat System
1/10/2008

SpaceDev/Starsys Acquired by SNC
12/16/2008

How did SpaceDev Start the Dream Chaser Journey:

$90k California Space Grant Part 1: 12/2004 to 2/2005

First Dream Chaser was based on X-34
Initially for Suborbital Flights 12/2004
Then 2/2005 We Changed to Orbital…Why??

SpaceDev Jan to March 2005

X-34 Study Team

Key Personnel

1. **Dan Rasky NASA Ames**
2. **Phil Smith - California Space Grant Foundation**
3. **David Kinney - NASA AMES (Not Shown)**

<u>X-34 Assets stored at North Base Edwards</u>

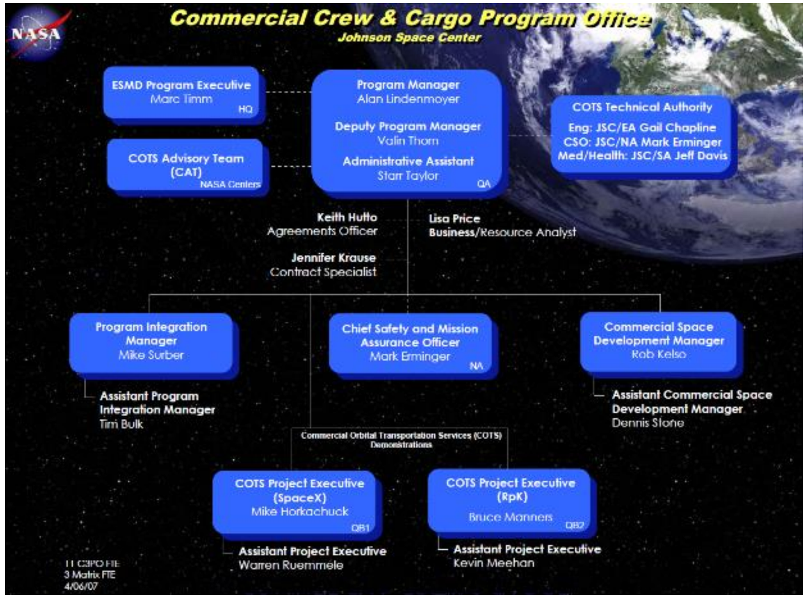
- **A1: airframe is air drop vehicle only, no TPS, no propulsion**
- **A2: 95% assembled, fuel system, no motor, 67% TPS covering airframe, Circa parts are in boxes**

A2 (2/05)

A1 (2/05)

COTS Initial Rumors 2/2005

Space Grant Part 2: 3/2005 to 7/2005 + Increase From $90K to $110 K



- 2/2004 NASA Awarded Kistler Aerospace $227 M for K-1 Launch Vehicle
- Elon Musk Protested and NASA withdrew contract after GAO ruling
- COTS Rumors of a pending proposal 2/2005

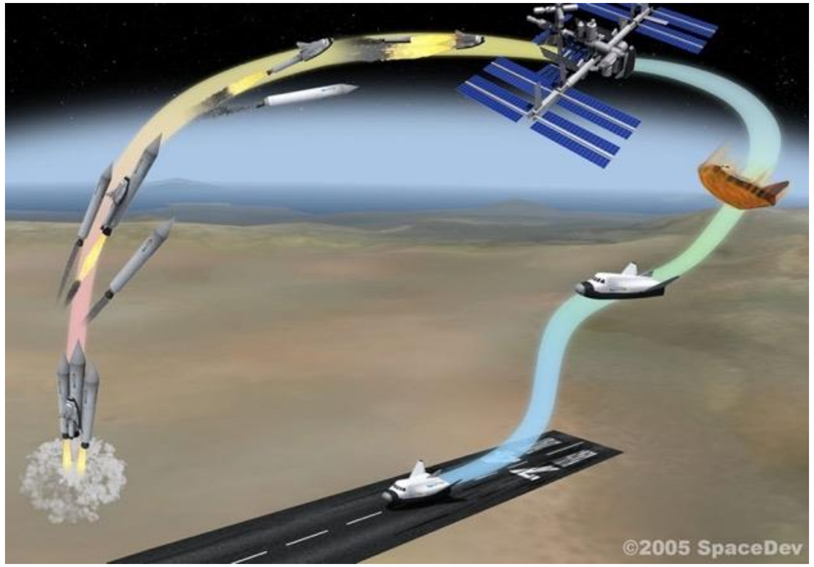
SpaceDev Pivots from X-34 to HL-20 3/2005

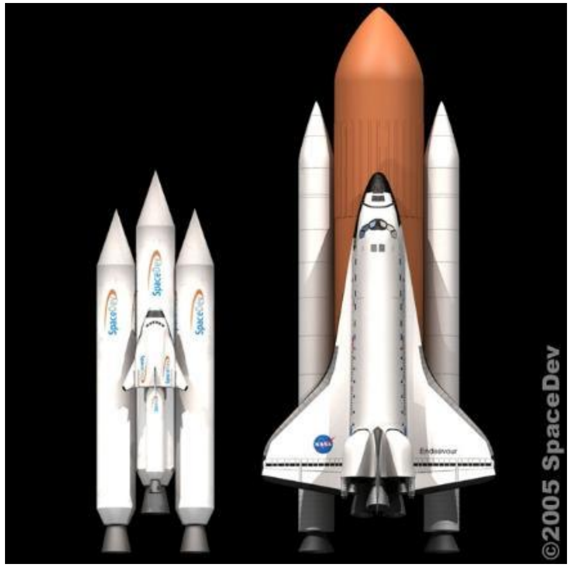
Based on Recommendation from David Kenney (NASA Ames):

" You very heard about HL-20" + Thermal Analysis on Re-Entry of X-34 vs HL-20

NASA COTS Key Personnel:
Laura Segarra
and
Valin Thorn

SpaceDev Final CA Space Grant Briefing to NASA AMES 7/2005





LaRC HL-20 Mock-Up 4/2005: Jim Benson + Frank Taylor

LaRC Key Personnel: Dream Chaser's True Believers

John Martin

Glenn Bobskill

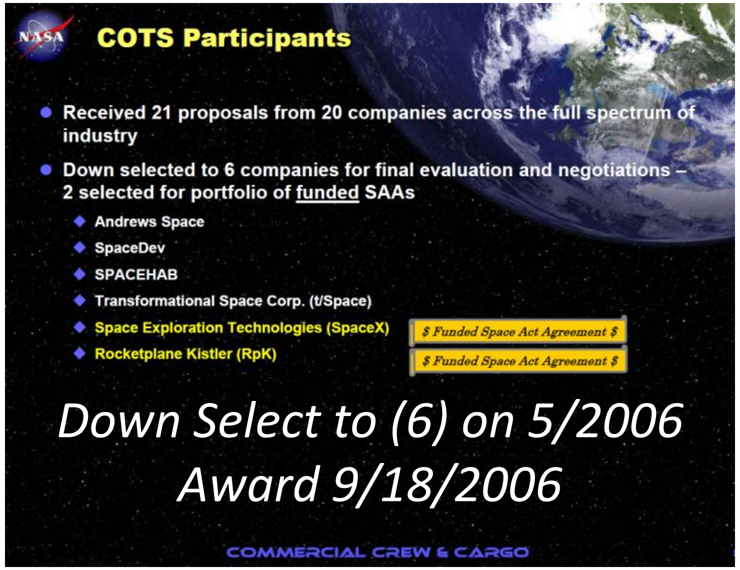
Bruce Jackson

Dream Chaser – Based on HL-20:
Developed on the Previous Efforts of
NASA LaRC in 80's and 90's
Per Walt's Earlier Presentation

Additional LaRC Personnel Who Supported HL-20 to Dream Chaser:

- David Glass, David Dress, Walt Engelund, Tom Horvath, Dale Reed, Jason Chenenko
- Kelly Murphy, Karen Berger, Bruce Owens, Chris Giersch, Ajay Kumar
- Clayton Turner, Lesa Roe, Long Yip, Judy Ward, George Ware, Kay Wurster
- Charles Cockrell, Mike Kirsch, Wally Vaughn, Andrew Carnell, Brian Barmore
- Stan Smeltzer, Max Blosser, Chuck Leonard, Ernie Mackley, Allen Wihite
- Julie Fowler, Melinda Cagle, David Piatak, Martin Sekula, Vince Zoby
- Matt Rhode, Tom Wolters, Bill Woods, Chris Cruz, Wallace Harrison

SpaceDev Dream Chaser Journey COTS I:
1/2006 to 9/2006



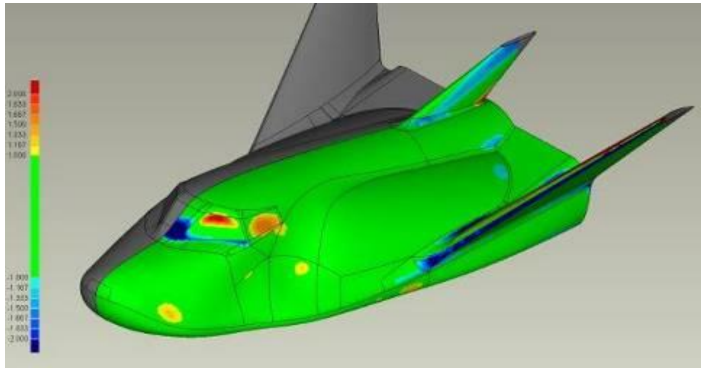
2/2004 NASA Awarded Kistler Aerospace $227
Elon Musk Protested and NASA withdrew contract after GAO ruling
COTS Rumors of a pending proposal 2/2005
NASA COTS Proposal Announced 1/18/2006
Proposal Submittal 3/2/2006
Finding (#1 to #5) 6/2006 to 7/2006
Final NASA HQ Briefing 8/2006
Award 9/2006 to SpaceX + Rocketplane Kistler
"First Phoenix Moment"

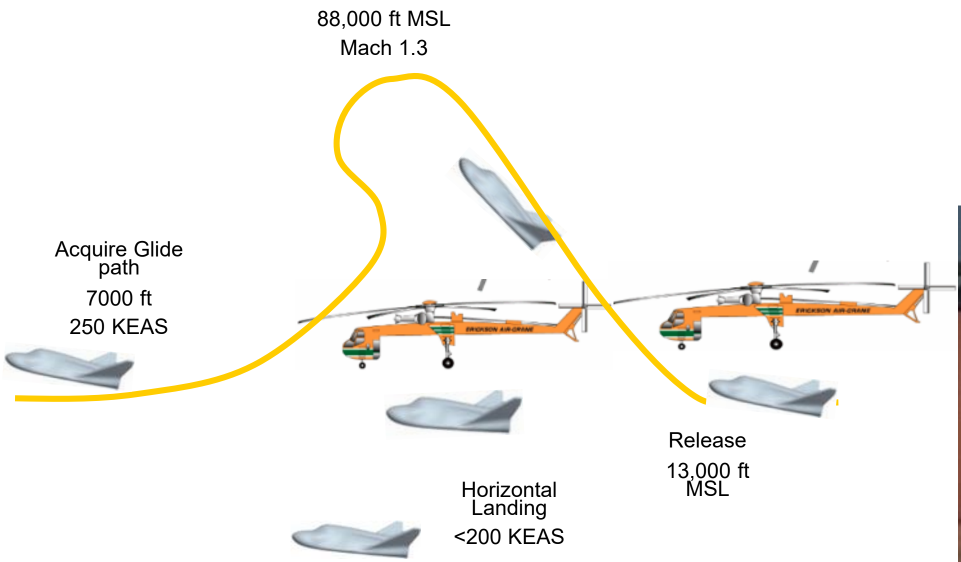
SpaceDev COTS I Proposal Team Jan to Aug 2006

2007 – 2009
JSC/SPDV *Un-Funded* SAA Milestones

Milestones Completed:

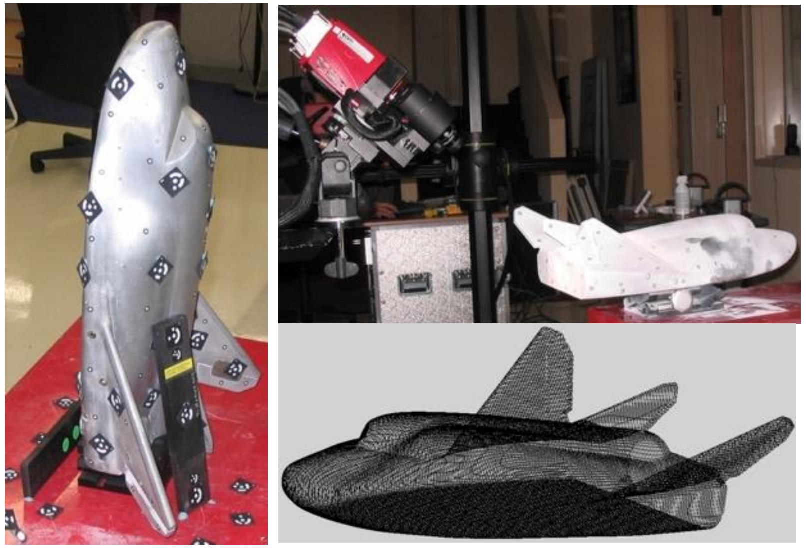
1. Outer Mold Line Definition 6/2007
2. Suborbital Flight Test Plan 9/2007
3. Hybrid Rocket Motor Preliminary Design Review 12/2007
4. Hybrid Motor Firing 9/2009





MileStone #1: Develop OML: HL-20 Wing Tunnel Model to Dream Chaser Baseline OML – 6/2007

Modification #1 to Physical HL-20 Model Included:
- Incorporated Wing Airfoil from LaRC Aero [L/D from 3.5 ish to 4.1 at Landing]
- Windshield
- Tip Fin Changes



Transonic wind tunnel model was digitized and output as a point cloud

Airfoil cross section Tip Fins replace slab Tip Fins

Scanned data was paramaterized and lofted into a useful ProE surface model by surfacing expert Roger Hayes and Modified by SpaceDev's Jeff Hickerson

Roger Hayes

Jeff Hickerson

Cateye windshield replaced with sloped, 5 facet windshield similar to full scale mockup

COTS-2 Competition 10/2007 to 2/2008

COTS-1

Rocketplane Terminated 10/2007

COTS-2 Competition

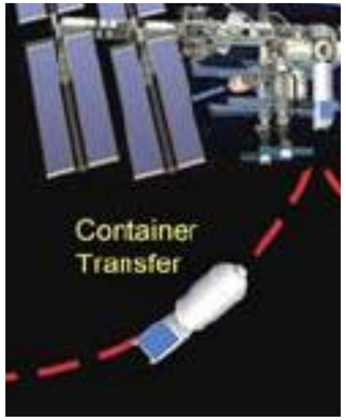
10/22/2007 RFP released

2/19/2008 Awarded to Orbital

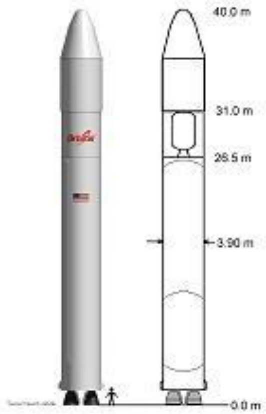
Second Phoenix Moment

- SpaceDev vs 9 Others:
  - Andrew Space
  - Boeing Houston ???
  - CSI/Loral
  - *Orbital Science*
  - PlanetSpace
  - SpaceHab
  - SpaceX
  - T-Space
  - TGV Rocket???

Andrew Space



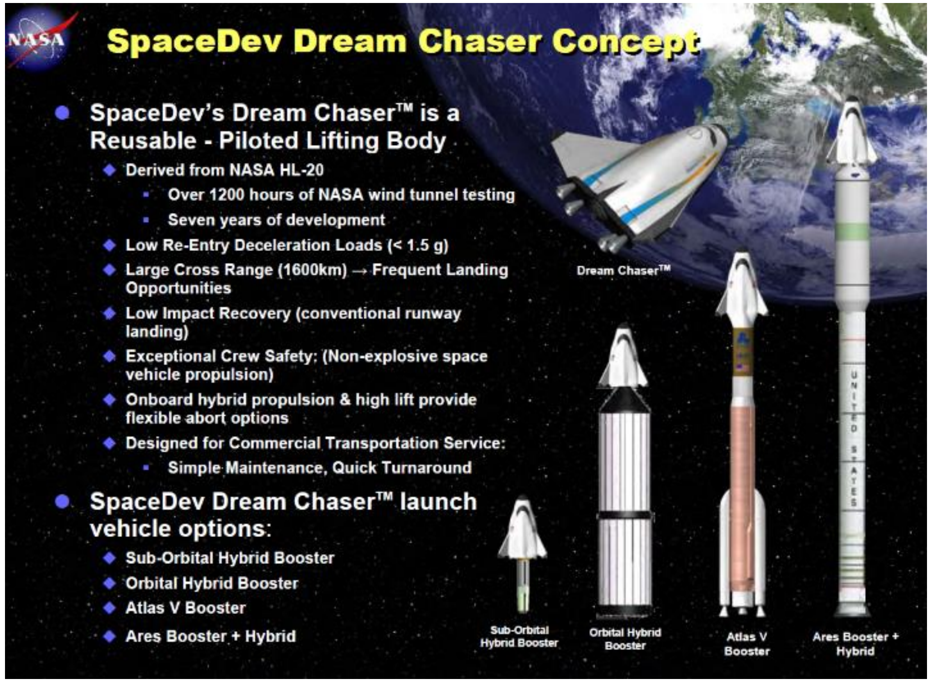
CSI/Loral

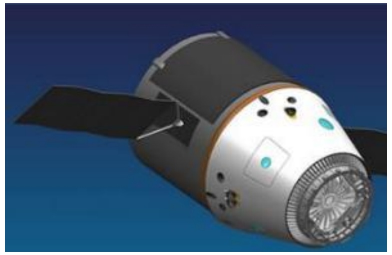


Orbital Taurus II

PlanetSpace

SpaceHab





SpaceX Dragon

T-Space

SpaceDev's Dream Chaser™

SpaceDev/SNC Internal Funded Efforts 2007 to 2009

ULA Key Personnel:
Bernard Kutter, Mike Holguin, Jeff Patton

4/10/2007 ULA/SpaceDev MOU Signed

Project Description

•Program to initialize development of the Dream Chaser for a NASA Human Commercial Transportation System to the ISS

Technical Objectives

•Develop system requirements for human transportation system to International Space Station
•Define the baseline configuration of the vehicle
•Establish orbital launch vehicle launch vehicle configuration and interface
• Initial trajectory analysis for orbital flights
•Business case definition for suborbital flights and other markets

SpaceShipOne
2004
16 klbf SpaceDev hybrid)

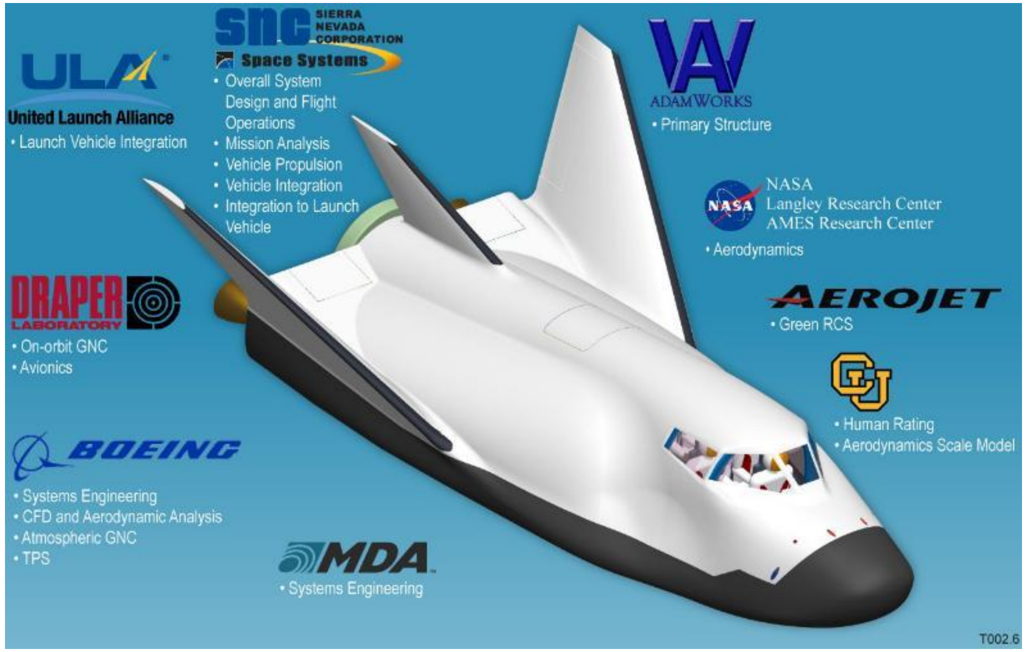
SpaceShipTwo
2008
(70 klbf SNC hybrid)

SpaceDev at Space Symposium
4/2008
Buzz Aldrin

Jim Benson

- Founder of SpaceDev
- Company CEO from 1997 to 9/2006
- Sold 2 successful software companies and became a retired millionaire (Compusearch and ImageFast of McLean Virgina)
- Famous line: “Onward and Upward”
- Founded the … Benson Space Company - 2007
- Died of brain tumor in Oct 9, 2008 at the age of 63

CCDev1 Proposal/Award 2009 to 2010



SNC CCDev 1 Proposal Team 2009

The Announcement was released on August 10, 2009. It divided the proposals into three sections with one appendix, all due on September 22, 2009. Section 1 was an Executive Summary, Section 2 was the Commercial Crew Capability Maturation Plan, and Section 3 required Company Information. The appendix contained a proposed Space Act agreement. Proposals were received from the following companies (participants):

Ad Astra Rocket Company	Odyssey Space Research
AlphaSpaces	Orbital Outfitters
Andrews Space	Orbital Sciences Corporation
ARES	Orbital Technologies
ATK	Paragon Space Development Corporation
Ball Aerospace	Planetspace
Bigelow Aerospace	S.T.A.R. Systems
Blue Origin	Sierra Nevada Corporation
Blue Smoke	SpaceED – U.C. Davis
The Boeing Company	Space Exploration Technologies (SpaceX)
Dii Aerospace Laboratories	Stone Aerospace
Exploration Partners, LLC	The Expanding Universe, LLC
Firestar Engineering, LLC	Thomas Lee Elifritz
Global Outpost	United Launch Alliance (ULA)
HMX, Inc.	Universal Space Lines
IE Group, LLC	Universal Transport Systems
KT Engineering	Vivace
Oceaneering Space Systems	XCOR Aerospace

Blue Origin	$3.7 million
The Boeing Company	$18 million
Paragon Space Development Corporation	$1.44 million
Sierra Nevada Corporation	$20 million
United Launch Alliance	$6.7 million

Geoffrey L. Yoder
Selection Authority

12-8-09
Date

Crewed Dream Chaser 2010 to 2014

CCDev1 + CCDev2 + CCiCap/CPC

Modification #2 to Dream Chaser OML Included:

- Wing Airfoil Change
- Elevon Size
- Lower Body Flap Size

Integrated Wind Tunnel Model: Crewed Dream Chaser on Atlas V 2014

ETA – Engineering Test Article Airframe - 2011

ETA – Engineering Test Team Article 6/2012

Escape Motor Firing 6/2013

Dream Chaser Team
ETA Captive Carry Testing - 8/2012
Aviation Week Cover - 10/1/2012

Dream Chaser Team
CCiCap 10/2013
Third Phoenix Moment

Dream Chaser Team
Termination of CCiCap 8/2014
Fourth Phoenix Moment

Cargo Dream Chaser - *Tenacity* 2015 to Now

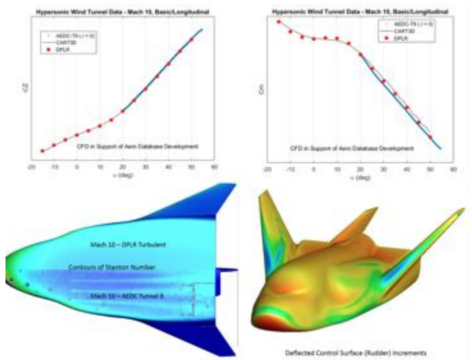
CRS2 Contract Award 1/14/2016

Modification #3 From Crew to Cargo Included (2015) SNC Funded:

- Added Cargo Module
- Solar Arrays
- Remove Windshield
- Folding Wings
- TPS Tile on Upper Surface
- No Escape Hybrid Propulsion
- RCS Changed from N20/Ethane to Peroxide/RP-1
- Launch Vehicle – ULA Vulcan

ETA Displayed at Space Symposium
Eren & Fatih Ozmen + VP Mike Pence
4/2018

Rebuild of ETA 2014 to 2017
Successful ETA Landing 11/11/2017



Mach 10 Wind Tunnel/CFD 2019

Tenacity Testing at Armstrong 2024

Dream Chaser Team Tenacity 10/2023

Thank You:

Frank Taylor
720-646-6023
frank.w.taylor1@gmail.com
https://www.linkedin.com/in/frank-taylor-84008ba8/