Hypersonics and Dream Chaser

Dr. John Olson

Vice President, Space Systems Group

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Hypersonics: Convergence

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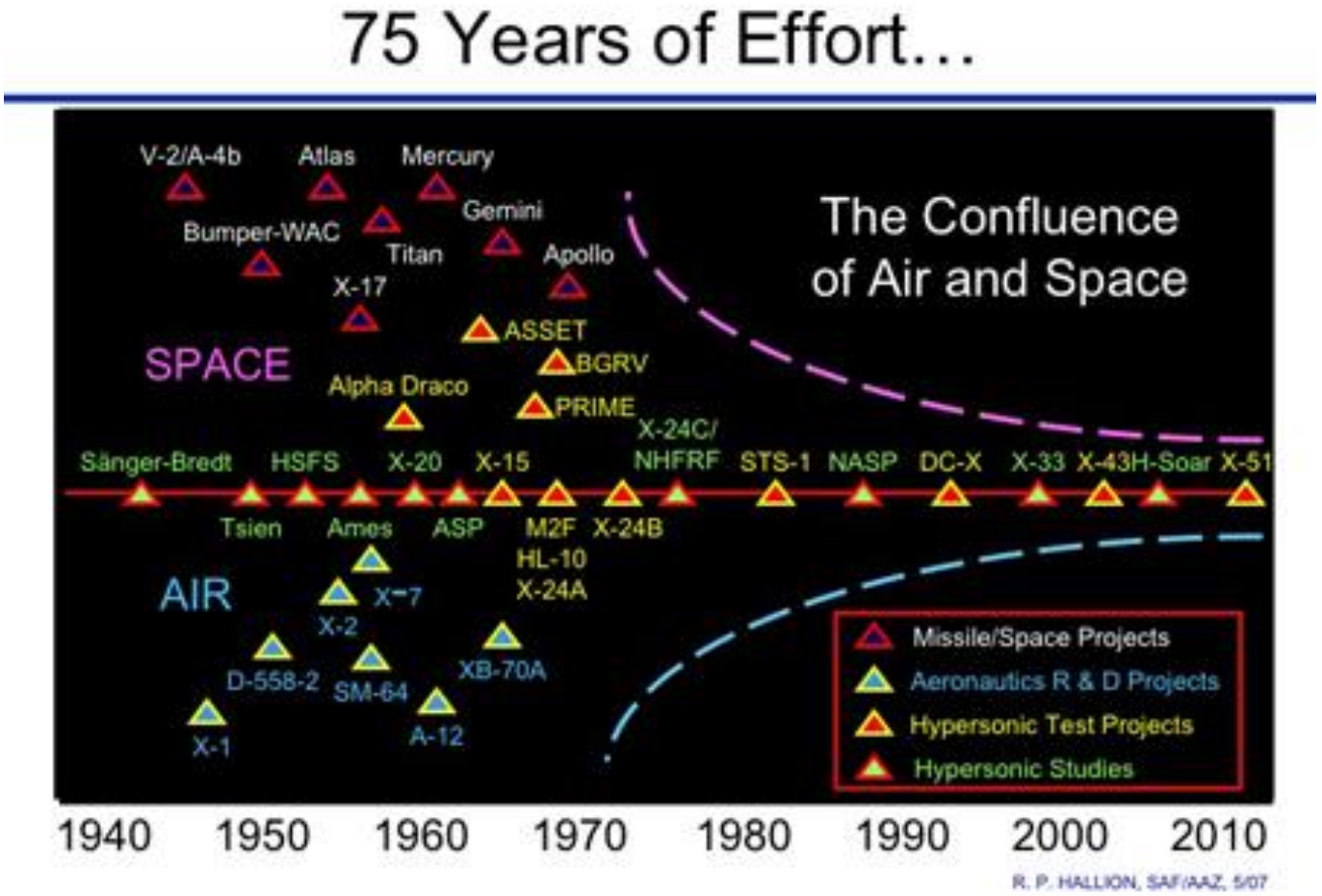
Hypersonics = Mach Number ≥ 5



US Hypersonics Quick Summary

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- **Current State:** White House: National Hypersonics Strategy, OSTP & DoD: Hypersonics Capability and Facility Report to Congress, US Air Force Hypersonics Plan, DARPA Hypersonics Plan, NASA Hypersonics Program
- **Focus Areas:**
  - Weapons, ISR, Access to Space
- **Challenges/Opportunities:** Technology, Budgets, Programmatics, Facilities, Ops
- **Drivers:**
  - **Integrated National Hypersonics Plan:** To include Requirements, Architectures, Systems, RDT&E needs, Ranges/Facilities/Infrastructure, and Personnel plan
  - **Policy:** A stable National and Department/Agency policy
  - **Budgets:** A stable, requirements-based multi-year budget

Integrated Hypersonics Strategy & Plans

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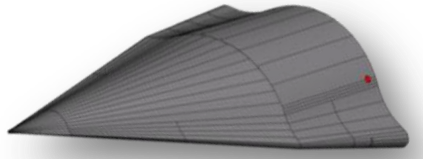
- **Hypersonics Technology Maturation and Foundational Research**
  - NASA's Hypersonics Project: Reusability & Re-entry
  - DARPA's Integrated Hypersonics Program – Re-planned
  - Fuel development
  - High-Speed ISR S&T

- **X-51A Waverider**
- **High Speed Strike Weapon (HSSW)**
  - Initiated to design and flight test technologies

- **Conventional Prompt Global Strike (CPGS)**
  - DARPA HTV-2
  - Army Advanced Hypersonic Weapon (AHW)
- **DARPA's Tactical Boost Glide (TBG)**
- **Hypersonic International Flight Research and Experimentation (HIFiRE)**
  - Bi-lateral arrangement: USAF AFRL & Australian DoD (DSTO)



Hypersonics: *Building on Recent Success*

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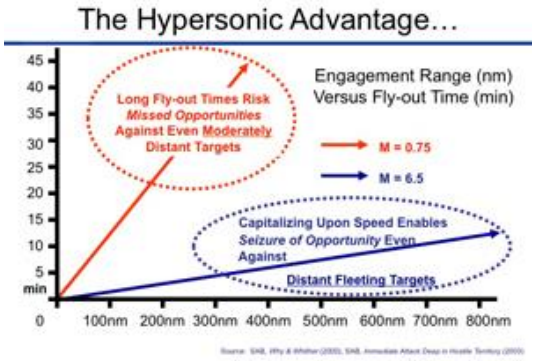
- **X-51A**
  - M5+ w/JP7 Fuel; Air launched from B-52
  - 1st flight in May 2010 partial success
  - 2nd flight in June 2011 fuel system issues
  - 3rd flight in August 2012 flight controls issues
  - 4th flight in May 2013 SUCCESSFUL!!!
    - 4+ mins of powered flight



- **CPGS**
  - High Mach boost glide; advanced materials and thermal protection
  - HTV-2: two flight tests, did not meet objectives; substantial data obtained
  - AHW: first flight test met objectives

- **HIFiRE**
  - Foundational flight test experiments; collaboration with Australia
  - 4 successful flight tests
  - Engineering systems and avionics, aerodynamics and aero heating, hydrocarbon scramjet operability

NASA Hypersonics Project: *Reusability and Re-entry*

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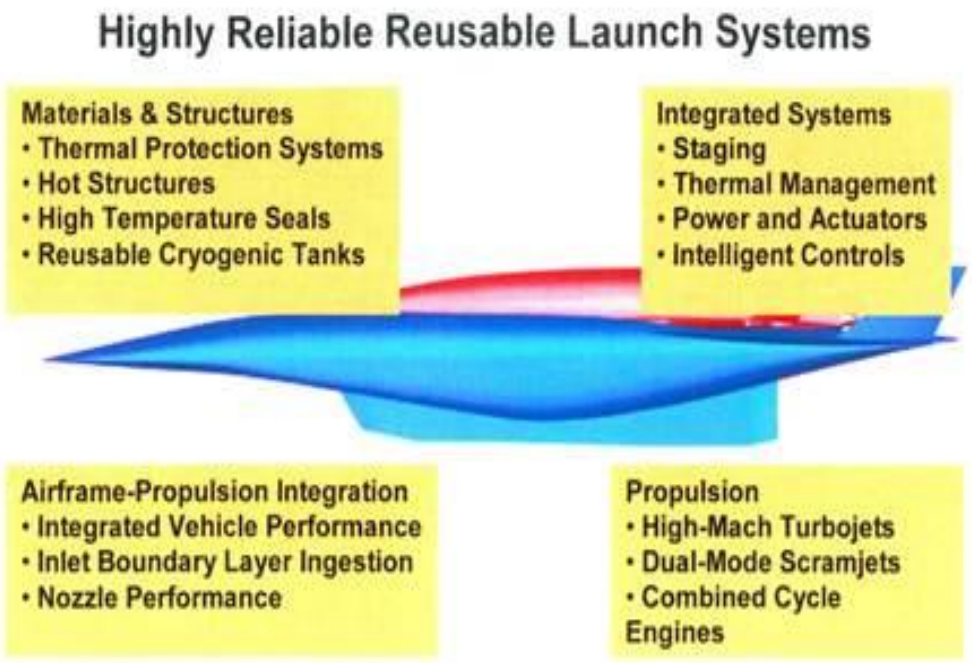
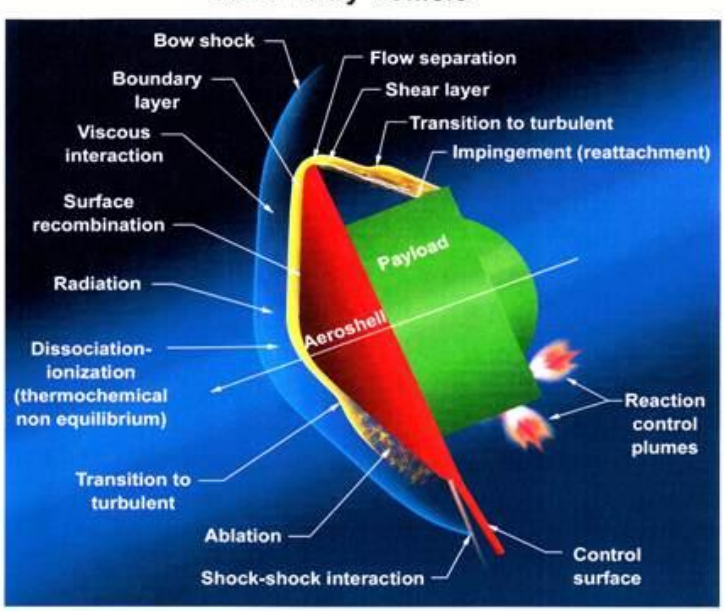
Development and validation of foundational tools and technologies for two hypersonic system classes: the Highly Reliable Reusable Launch Systems (HRRLS) class, an airbreathing space launch vehicle, and the High Mass Mars Entry Systems (HMMES) class, a large vehicle focused on transporting humans to and from Mars.






NASA
United States

Dream Chaser Space System

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- Capable of 7 crewmember transport for the International Space Station and LEO
  - Meets NASA requirements for 4 crew to and from ISS
  - Also accommodates pressurized cargo
- Non-toxic Main Propulsion System (MPS) motors used 3rd stage insertion, launch abort, orbital translations, and deorbit maneuver
- <1.5g re-entry profile and >1000 nm cross-range capability
- Integrated on the Atlas V launch vehicle, but Launch-vehicle agnostic
  - Mature, reliable, and compatible with 100+ consecutive Atlas (46 consecutive Atlas V launches)

Dream Chaser

Evolution of Dream Chaser

NASA's HL-20 Spacecraft (Russian BOR-4 heritage)

- >1200 wind tunnel tests
- Trajectory studies
- Handling evaluations
- Abort landing simulations
- Ergonomics and egress
- Fabrication and operations

Building Upon Space Shuttle Heritage

- Leverages 40 yrs of Shuttle design, technology development, and operational experience
- Reusable, Reconfigurable Runway-Landing Vehicle
- Ideally Suited to Host a Range of Other Missions

SNC's Dream Chaser Vehicle

- Incorporates 10+ years of research, design, development, and testing
- Modern materials, Aerodynamic data
- Improved flight control surface design
- Significant CFD analysis, Wind Tunnels
- Trajectory refinement
- Component and wind tunnel testing
- Launch vehicle integration
- Flight simulation

1970 1980 1990 2000 2010

Dream Chaser Historic First Flight – Much More History to Make!

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Space Shuttle Enterprise
October 26, 1977
Edwards AFB, Runway 22L

Dream Chaser Spaceship
October 26, 2013
Edwards AFB, Runway 22L

Dream Chaser Development Status

- Completed 29 Milestones under the NASA Commercial Crew Program
- Engineering Test Article (ETA) Tested & Flown; Fly again Fall 2014
- Orbital Test Vehicle (OTV) Under Construction, First Orbital Flight 2016

Our NASA Mission:
Crew Transport Services to the ISS

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DC Concept of Operations

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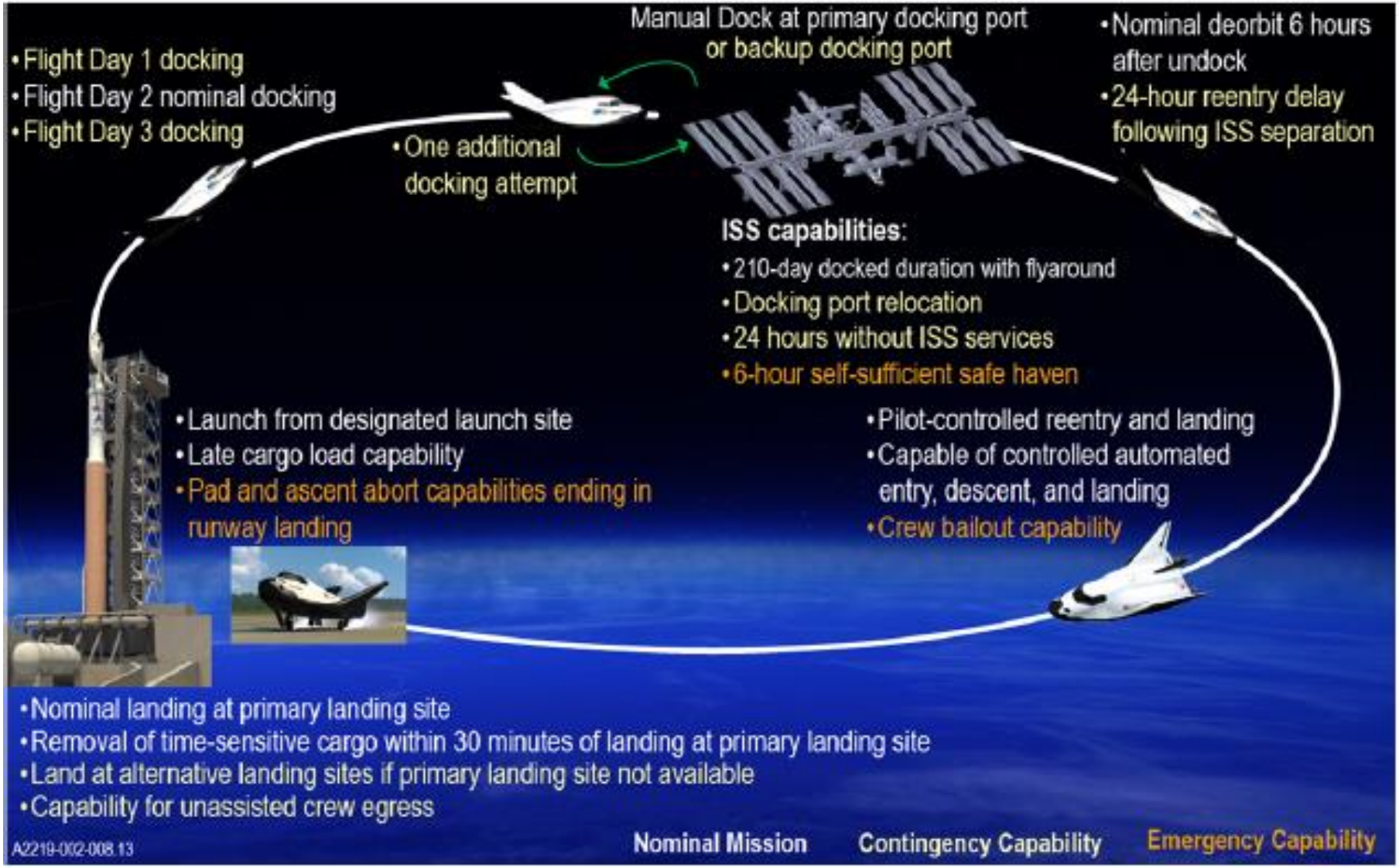

Dream Chaser Hypersonics Overview

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- **The Dream Chaser program is completing its hypersonic verification through both analysis and test**
  - Aerodynamic testing in wind tunnels
  - Thermal Protection testing in wind tunnels
  - Computational Fluid Dynamics (CFD) analysis with various software codes
  - System, sub-system, and component testing, including sensors and controls
- **Dream Chaser re-entry is comparable to Space Shuttle with regards to flight conditions in the hypersonic regime**

Dream Chaser Hyper Analysis & Test

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- Computational Fluid Dynamics (CFD) Analysis
- Wind Tunnel Testing: Subsonic, Transonic, Supersonic, Hypersonic
- 2 Orbital Test Flights: OFT-1 (2016) and OFT-2 (2017)
- Powered Flight Testing
- Lift to Drag Ratio (L/D): Similar to Shuttle
- Trajectory optimization: Crossrange 1,100+ nm
- Aero database reconstruction → Validate models
- Mach 25 re-entry
- High-altitude Energy Management (Same as Shuttle) S-turns
- Heading Alignment Cone (HAC) Energy Management
- Sensors and Data throughout flight profile
- Pressure: Static, Dynamic, Base
- Temp: Profile, Peak, Rates, Loads, Thermal Diffusivity

Hypersonics Wind Tunnel Testing

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Extensive Testing with 11 state-of-the-art wind tunnels used

- NASA Ames Research Center
- NASA Marshall Space Flight Center
- NASA Langley Research Center
  - Hypersonic, aerodynamic wind tunnel testing at LaRC
  - 6% Dream Chaser OV Model
  - Approximately 2,000 Runs
    - Alpha sweeps (continuous and pitch-pause)
    - Beta sweeps (continuous and yaw-pause)
    - Mach sweeps
    - Control surface sweeps

First Orbital Launch

November 2026

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Space Systems

It all starts with a Dream…Hypersonics and Space are the Future…today!

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Summary

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- **Air and Space platform S&T and development making progress, contributing to US national strategy/capability**
  - Investments in R&D, Facilities/Infrastructure, Test, Personnel, and Programs are producing results
  - Several successful efforts
- **Hypersonics provide important capabilities**
  - Speed solves problems and creates opportunities
  - Reusability aids affordability
  - Driving requirements in Air & Space will push results
- **Stability in focus, funding, and foundation building is key**
  - Building on recent successes in hypersonics R&D
- **SNC's Dream Chaser program is revolutionary!**

Dawn of a Dream!

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Thank you!