Circulation Control in NASA's Vehicle Systems

Paul Rich, Bob McKinley, and Greg Jones

Langley Research Center

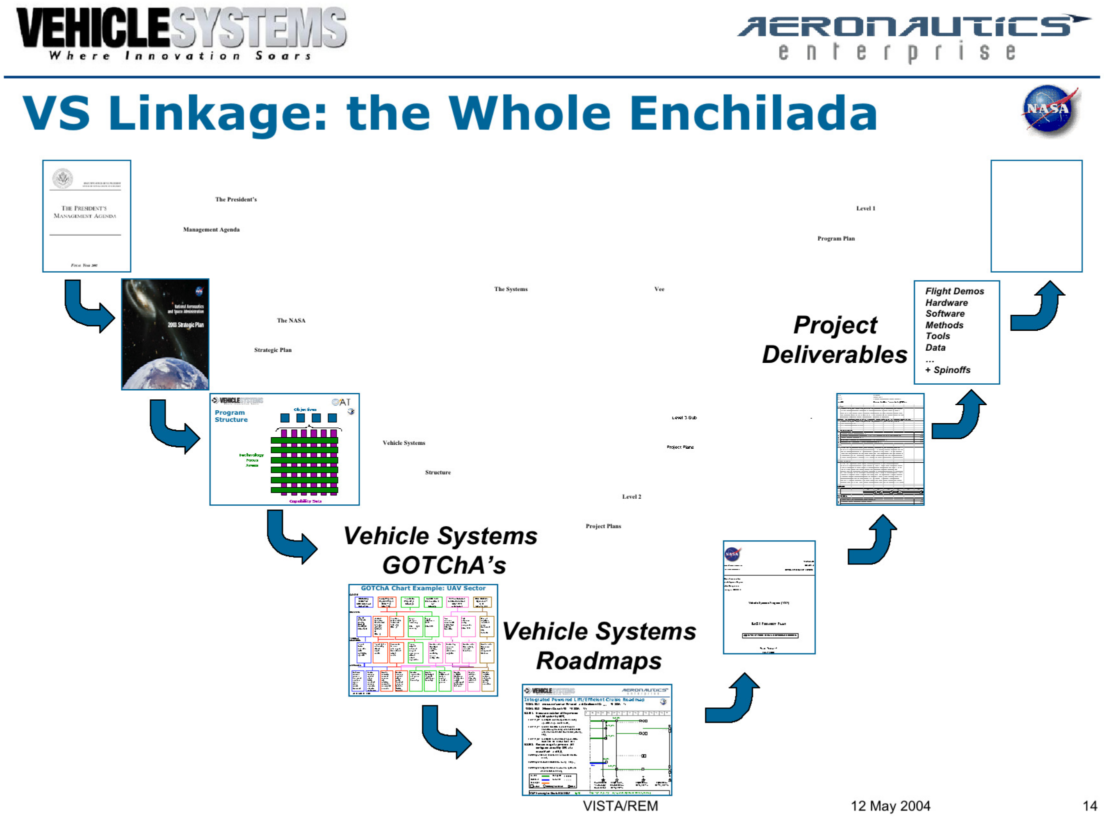
Specific to the application of any technology to a vehicle, such as circulation control, it is important to understand the process that NASA is using to set its direction in research and development. To see how circulation control fits into any given NASA program requires the reader to understand NASA's Vehicle Systems (VS) Program. The VS Program recently celebrated its first year of existence with an annual review—an opportunity to look back on accomplishments, solicit feedback, expand national advocacy and support for the program, and recognize key contributions. Since its formation last year, Vehicle Systems has coordinated seven existing entities in a streamlined aeronautics research effort. It invests in vehicle technologies to protect the environment, make air travel more accessible and affordable for Americans, enable exploration through new aerospace missions, and augment national security. This past year has seen a series of valuable partnerships with industry, academia, and government agencies to make crucial aeronautics advances and assure America's future in flight.

The Vehicle Systems Program is made up of seven core projects, including Efficient Aerodynamic Shapes and Integration (EASI) and Flight and Systems Demonstrations (FSD). In addition, an internal reorganization last year produced six vehicle sectors, managed by a group of NASA strategists—the Vehicle Integration, Strategy, and Technology Assessment (VISTA) Team. Vehicle sector managers provide near- and long-term planning for the projects in order to align aeronautics research with national and Agency priorities. Through technology integration and "roadmaps," which track VSP investments to minimize redundancy, VISTA synthesizes project activities to meet a set of common goals. The Project teams execute work for the program, and using Program resources, they are responsible for delivering technologies that meet the goals defined through the VISTA activities.

VS Projects cover a wide scope. From the Quiet Aircraft Technology (QAT) Project, which works to mitigate aircraft noise impacts on travelers and airport neighbors, to the Low Emissions Alternative Power (LEAP) Project, which develops energy-efficient alternative propulsion and power systems, the VSP promises a variety of applications for industry, the military, and civilians. Advances have already been made in the Autonomous Robust Avionics (AuRA) Project, among others. AuRA team leaders are creating on-board flight systems to reduce human interaction, with eventual plans for unmanned aerial vehicles and aircraft technology for unskilled operators. The Ultra Efficient Engine Technology (UEET) Project has also introduced innovative technologies. To combat global warming, UEET is developing combustors for gas turbine propulsion systems capable of reducing nitrogen oxide emissions by 70% at takeoff and landing.

The annual review recognized the hard work of a number of employees and outlined plans for even greater future successes. The Extreme Short Takeoff and Landing (ESTOL) and the Rotorcraft (RC) sectors will continue to direct project activities toward vertical or near-vertical takeoff and landing research and development. The Personal Air Vehicle (PAV) and Uninhabited Air Vehicle (UAV) sectors will encourage aeronautics innovations that eliminate the need for a professional pilot, including affordable aircraft for ordinary Americans. Finally, the Supersonic Aircraft (SSA) and Subsonic Transport (ST) sectors will work to maximize efficiency and strive for global reach.

With sector oversight now providing strategic direction, the VSP projects will move forward with their near-term focuses. Continual self-correction and program evolution will help yield valuable aeronautics advances. Much of the program's success this year was due to the advent of VISTA and the incorporation of sectors to coordinate project activities. By linking strategy and implementation, the VSP has established clear organizational goals for its active projects—guidelines that will operate throughout the year to ensure that next year's annual review is equally outstanding.



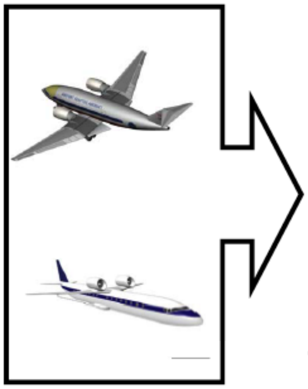
The Vehicle systems program has a number of revolutionary projects leading the Aerospace industry into an exciting future. Circulation control concepts may play a role in several of these projects. The projects discussed below are likely candidates where circulation control may have the largest impact in the near term.

ITAS (Integrated Tailored Aero Structures) Project

The primary focus of the ITAS project is to develop ultra-light smart materials and structures, aerodynamic concepts, and light weight subsystems to increase vehicle efficiency, leading to high-altitude long-endurance vehicles, planetary aircraft, advanced vertical and short takeoff and landing vehicles and beyond.

This project is divided into five areas: Actively Tailored High-Lift Systems, Highly-Loaded Lightweight Structures, Adaptive Ultra-Lightweight Airframe Systems, Planetary Flight Vehicles, and Multifunctional Structures Foundation Technologies.

An example of a sub-project in the Actively Tailored High-Lift Systems area is the Integrated Wing Concepts for ESTOL. The challenge in this area is to increase the circulation of the low speed powered high lift system by 50% to generate more lift on takeoff while decreasing the drag to maintain efficient cruise. Figure 1 illustrates the set of capabilities for a notional ESTOL vehicle. Nominally one can achieve many of these capabilities, but the challenge for ESTOL is to meet all of the capabilities at the same time. Figures 2 and 3 are examples of GOTChA and roadmaps related to ESTOL.



Required Capability	SOA	5-Years	15-Years
Balanced Field Length	4,000 ft	2,000 ft	2,000 ft
T/O & Landing Speed	120 kts	65 kts	50 kts
Turn Radius in Terminal Area	1 1/4 nm	1/2 nm	1/4 nm
Cruise Mach	0.60	0.70	0.80
Range	1,000 nm	1,400 nm	1,400 nm
Payload	90 PAX	90 PAX	90 PAX
Noise Footprint W/I Airport	No	Yes	Yes
Terminal Ops	CTOL IFR	* CAT IIIA	* CAT IIIC

Figure 1. Targeted ESTOL Notional Vehicle Capabilities.

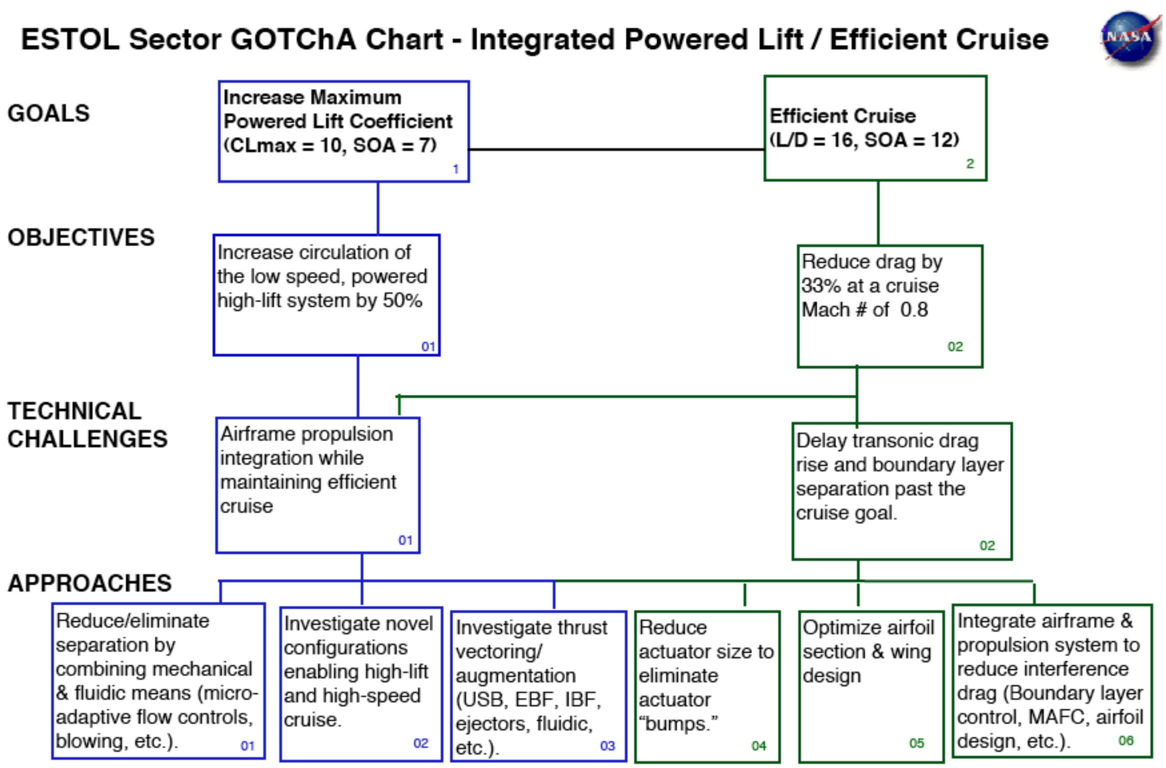


Figure 2. Example of GOTChA chart for ESTOL (living document that updates regularly).

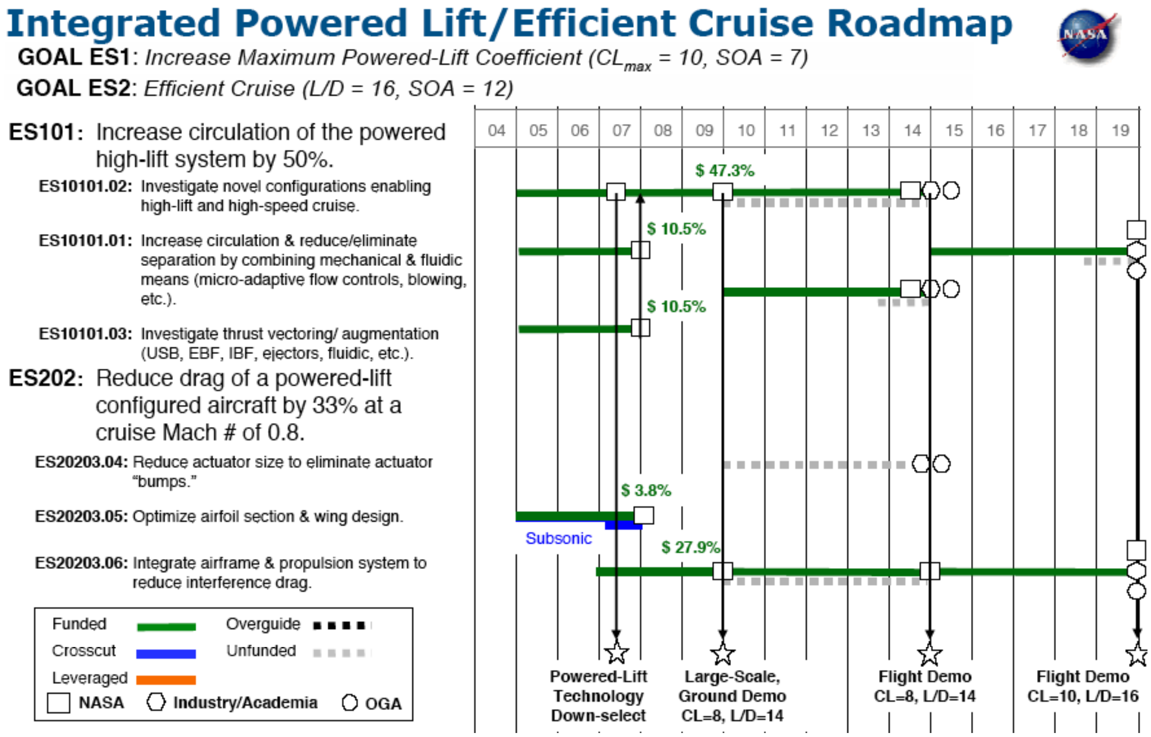


Figure 3. Example of a portion of the roadmap for ESTOL (living document).

Other sub-projects within the Actively Tailored High-Lift Systems area include morphing leading edges for the subsonic transport and investigations into the Aero-Propulsion-Servo-Elastic technology. In the Highly-Loaded Lightweight Structures area, sub-projects are enabling technology to reduce the fuselage structural weight of the Blended Wing Body aircraft to a range competitive with conventional air transports.

A subproject in the Adaptive Ultra-Lightweight Airframe Systems area is investigating weight reduction for High Altitude Long Endurance (HALE) vehicles to improve endurance payload, launch and recovery, performance under adverse flight conditions and durability.

In the Planetary Flight Vehicle area a number of sub-projects are focused on establishing a mature baseline vehicle for Mars exploration for a potential 2011 mission. These sub-projects will establish aerodynamic performance, demonstrate flight controls, evaluate propeller and other new vehicle concepts, including VTOL and mother ship concepts.

Examples of sub-projects in the Multifunctional Structures Foundation Technologies area are Bio-inspired Nano-structured Materials Development and Adaptive Aero Structures. Both of these sub-projects, using adaptive structures and micro-flow concepts, will significantly reduce vehicle weight to improve community access and enable new missions.

EASI (Efficient Aerodynamic shapes and Integration) Project

The primary focus of the EASI project is to improve aerodynamic efficiency, structures, materials technologies, and design tools and methodologies to reduce fuel burn and minimize environmental impact and enable new vehicle concepts and capabilities for public mobility and new science missions.

This project is divided into 4 areas: Configuration and Component Aerodynamic Technology, Aerodynamics for Heavy Lift Rotorcraft, Variable Fidelity Conceptual Design Tool, and Computational Methods for Flight Performance Prediction.

One of the sub-projects under Configuration and Component Aerodynamic Technology is the Blended Wing Body Flight Dynamics and Control effort. One of the near-term tests uses a 5% dynamically scaled free-flight model to characterize 1-g departures. A free-flight test in a NASA Full Scale Wind Tunnel will be conducted to assess envelope protection schemes, assess asymmetric thrust control limits, assess center engine thrust vectoring control and assess 1g-departure onset control. Other contemplated tests include high Reynolds number transonic stability and control characterization. Another subproject on Advanced Wing Technology will be developing and testing a closed loop adaptive bump to minimize transonic wave drag.

A sub-project under Variable Fidelity Conceptual Design Tool is a "Conceptual Design Shop" which advances concept design state-of-the-art. This will enable NASA to design and assess unconventional atmospheric vehicle concepts and advanced technologies to meet NASA's aeronautics goals. The "Conceptual Design Shop" will incorporate variable fidelity analysis tools and methods, quantify uncertainty, and create a knowledge database for NASA.

One of the sub-projects under Computational Methods for Flight Performance Prediction is COMSAC (computational methods for stability and control). This effort will benchmark, validate and develop computational tools for the prediction and analysis of stability, controllability and flight dynamics of advanced aircraft. This will potentially lead to large reductions in test requirements in Stability and Control. Other sub-projects in this area are investigating 3-D Physics-based mesh adaptation technology and physics-based transition prediction for subsonic vehicles. Both of these latter efforts will support improved design techniques for the future.

A sub-project under Aerodynamics for Heavy Lift Rotorcraft is Large Lightweight Rotor Concepts. This effort will focus on identifying large, fast, long-range VTOL transports to revolutionize air transport.

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Future Vehicle Capabilities & the Potential Contribution of Circulation Control

NASA Circulation Control Workshop
Hampton, VA
16 March 2004

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Synopsis

- Vehicle Systems (VS) Program Overview
  - Drivers for the "new" Program
  - Semantics and Planning Constructs
  - Program Structure
  - So What?
- Future Vehicle Capabilities
  - History and Development
  - Status and Description
- Circulation Control as a Potential Solution
  - Relation to Sectors and Capabilities
- Summary
  - Next Steps
  - Points of Contact

National Policy Shift

- Federal R&D investment policies are no longer viewed as predominantly for national security but rather for **stimulation of national innovation, economic competitiveness, and basic health and science research**
- **Continual budget pressure** and a call for efficient and effective use of tax payer dollars, including those targeted for federal R&D
- Increased oversight of programs with **proof of return on the investment**
- Greater emphasis on science and engineering education and training
- Government investment in **R&D will continue to take a backseat** to that of industry

➡ ***New policies set by Congress, the Clinton and the Bush Administrations demand maximizing ROI through greater efficiency, accountability, and success of the U.S. science & technology portfolio and Agency programs***

Congressional Guidance

Recent Report Language Directed at OAT/NASA*

- "...continue to pursue actions and reforms directed at **reducing institutional costs**, including management restructuring, facility consolidation, procurement reform, and convergence with defense and commercial sector systems.."
- "…. should **invest in the types of research and innovative technology in which United States commercial providers do not invest**, while avoiding competition with the activities in which United States commercial providers do invest."
- "NASA and the Department of Defense should **cooperate more effectively** in leveraging the mutual capabilities of these agencies….. "
- "To achieve the public goal of price reduction and **innovation through competition**.."
- "...must articulate a comprehensive agenda and strategy through an agency performance plan for each of NASA's primary centers that identifies a **linkage between resources and activities in a way that guarantees an advanced technology strategy** that will ensure the preeminence of NASA in the area of space transportation, .., and aerospace technology, including aeronautical research and technology."

* Compiled from Authorization and Appropriations bills, fiscal years 1999 through 2003

Desirable Vehicle Systems Characteristics

- Defensible (to funders)
- Integrated (across program)
- Simplified (understandable)
- Focused (on goals)
- Innovative (technologically)
- Linked (to product users)

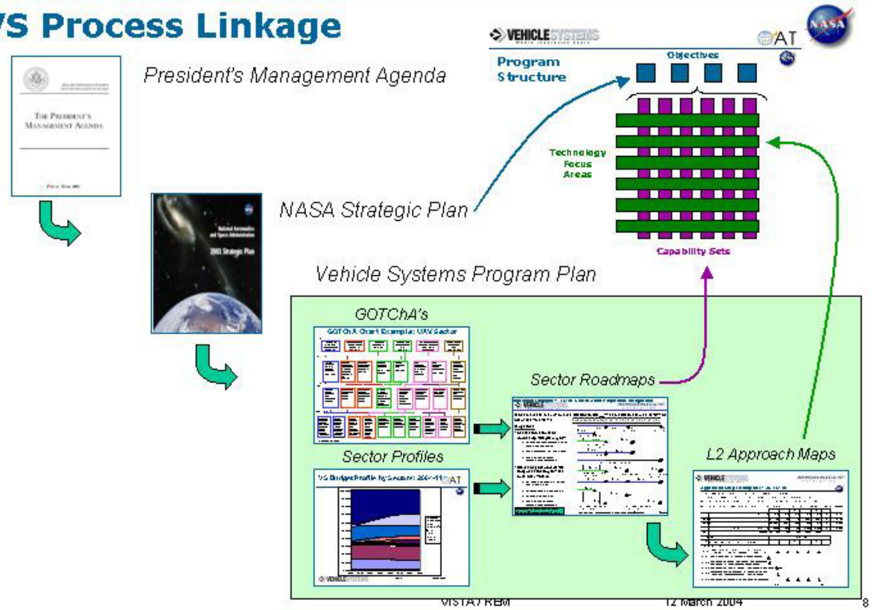
VS: Vocabulary

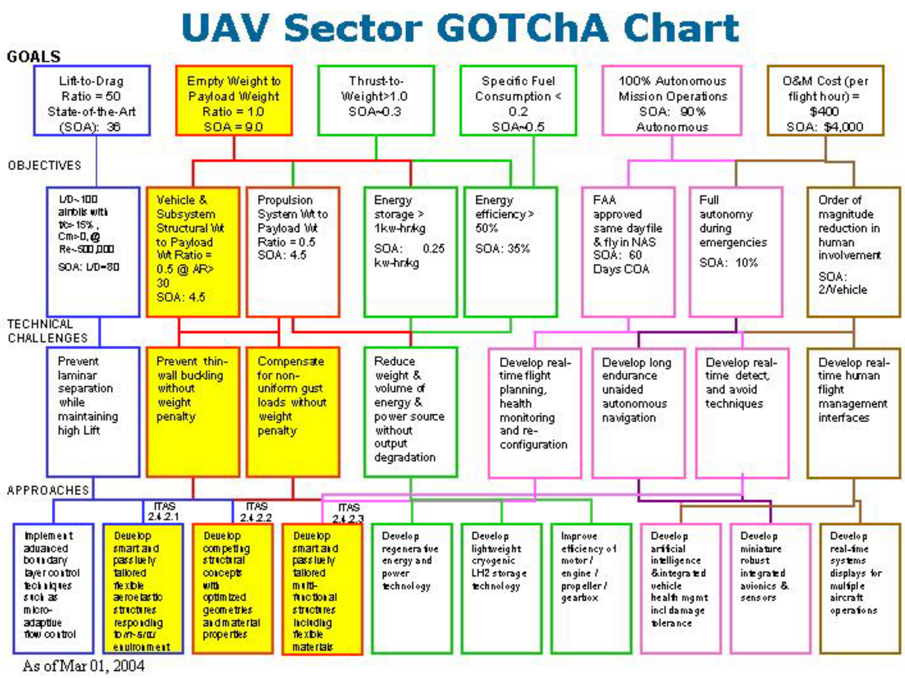
- Theme Objective
  - Objectives set by Aeronautics Theme that directly relate to public good Agency goals as defined in the NASA Strategic Plan.
- Program (a.k.a., Level 1 or L1)
  - An element of the Theme. Led by a Program Manager (L1) that defines a group of projects and processes aligned to accomplish goals that enable the Theme Objectives, e.g., Vehicle Systems Program.
- VISTA
  - Vehicle Integration, Strategy and Technology Assessment. VS Program component that defines technical strategy.
- Vehicle Sector
  - An element of VISTA. Led by a Vehicle Sector Manager (VSM) that defines the capabilities and priorities for a class of aircraft, then relates impact of associated work to the Theme Objectives. VSM's define the what and when of VS research.
- Capability Set
  - Definition of the capabilities desired for future aircraft and how it relates to public good .

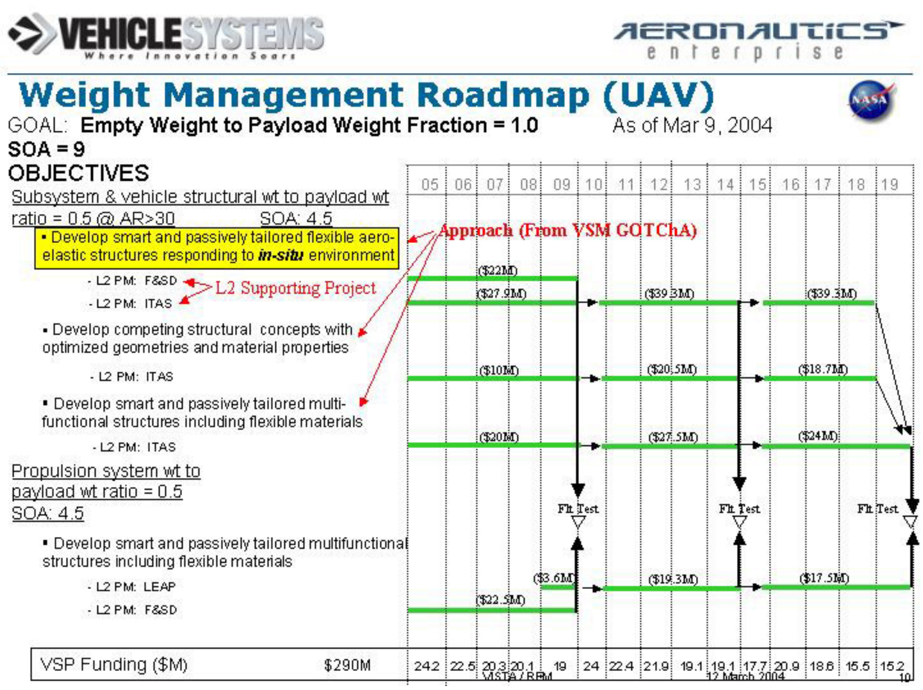
VS: Vocabulary, continued

- GOTChA Chart
  - Chart that relates Program **G**oals, **O**bjectives, **T**echnical **Ch**allenges and **A**pproaches in a top-down decomposition
- Roadmap
  - A depiction of the work required to achieve the Goals from the GOTChA chart. Includes related resources and projects that will execute the work.
- Technology Focus Area (a.k.a., Technology Foci)
  - Theme construct that describes enduring areas of research related to aeronautics. Functionally represented over a period of time by a project with start/end dates and deliverables.
- Project (a.k.a., Level 2 or L2)
  - An element of a Program. Led by a Project Manager (L2) that defines a group of activities (approaches to work) that deliver technologies that achieve the Objectives required to achieve the Goals required by a Vehicle Sector to reach a capability set. L2's define the who and how of VS research.
- Approach Map
  - A depiction of the work required to complete the Objectives that achieve the Objectives and Goals from the GOTChA chart. Includes related resources and specific activities required to complete the work.

VS Process Linkage




UAV Sector GOTChA Chart
GOALS
Lift-to-Drag Ratio = 50 State-of-the-Art (SOA): 36
Empty Weight to Payload Weight Ratio = 1.0 SOA = 9.0
Thrust-to-Weight>1.0 SOA~0.3
Specific Fuel Consumption < 0.2 SOA~0.5
100% Autonomous Mission Operations SOA: 90% Autonomous
O&M Cost (per flight hour) = $400 SOA: $4,000
OBJECTIVES
Vehicle & Subsystem Structural Wt to Payload Wt Ratio = 0.5 @ AR> 30 SOA: 4.5
Propulsion System Wt to Payload Wt Ratio = 0.5 SOA: 4.5
Energy storage > 1kw-hr/kg SOA: 0.25 kw-hr/kg
Energy efficiency > 50% SOA: 35%
FAA approved same day file & fly in NAS SOA: 60 Days COA
Full autonomy during emergencies SOA: 10%
Order of magnitude reduction in human involvement SOA: 2/Vehicle
TECHNICAL CHALLENGES
Prevent laminar separation while maintaining high Lift
Prevent thin-wall buckling without weight penalty
Compensate for non-uniform gust loads without weight penalty
Reduce weight & volume of energy & power source without output degradation
Develop real-time flight planning, health monitoring and re-configuration
Develop long endurance unaided autonomous navigation
Develop real-time detect, and avoid techniques
Develop real-time human flight management interfaces
APPROACHES
ITAS 2.4.2.1
ITAS 2.4.2.2
ITAS 2.4.2.3
Develop regenerative energy and power technology
Develop lightweight cryogenic LH2 storage technology
Improve efficiency of motor / engine / propeller / gearbox
Develop artificial intelligence &integrated vehicle health mgmt incl damage tolerance
Develop miniature robust integrated avionics & sensors
Develop real-time systems displays for multiple aircraft operations
As of Mar 01, 2004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Weight Management Roadmap (UAV)
GOAL: Empty Weight to Payload Weight Fraction = 1.0
As of Mar 9, 2004
SOA = 9
OBJECTIVES
Subsystem & vehicle structural wt to payload wt ratio = 0.5 @ AR>30 SOA: 4.5
• Develop smart and passively tailored flexible aero-elastic structures responding to in-situ environment
- L2 PM: F&SD
- L2 PM: ITAS
L2 Supporting Project
Approach (From VSM GOTChA)
• Develop competing structural concepts with optimized geometries and material properties
- L2 PM: ITAS
• Develop smart and passively tailored multi-functional structures including flexible materials
- L2 PM: ITAS
Propulsion system wt to payload wt ratio = 0.5
SOA: 4.5
• Develop smart and passively tailored multifunctional structures including flexible materials
- L2 PM: LEAP
- L2 PM: F&SD
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19
($22M)
($27.9M) ($39.3M) ($39.3M)
($10M) ($20.5M) ($18.7M)
($20M) ($27.5M) ($24M)
Flt Test
Flt Test
Flt Test
($3.6M) ($19.3M) ($17.5M)
($22.5M)
VSP Funding ($M) $290M
24.2 22.5 20.3 20.1 19 24 22.4 21.9 19.1 19.1 17.7 20.9 18.6 15.5 15.2

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ITAS Approach Map - 2.4.3.2

GOAL: Empty Weight/Payload Weight Ratio = 1.0, SOA = 9.0

OBJECTIVE: Vehicle & Subsystem structural weight/Payload Weight Ratio = 0.5 @ AR > 30 SOA: 4.5

TECHNICAL CHALLENGE 1: Prevent thin-wall buckling without weight penalty

TECHNICAL CHALLENGE 2: Compensate for non-uniform gust loads without weight penalty

TECHNICAL APPROACH 1: Develop competing structural concepts with optimized geometries & material properties

TECHNICAL APPROACH 2: Develop smart and passively tailored multifunctional structures including flexible materials

DESCRIPTION: Develop and validate competing lightweight airframe and subsystem structural concepts for FY09 & FY14 flights

	FY	05	06	07	08	09	10	
	FTE, direct	6.4	5.6	5.4	4.4	5.9	-	Totals
74.5%	Funding, IH, $K	2,212	2,053	1,958	1,607	2,481	-	10,311
25.5%	Funding, OH, $K	968	757	722	593	489	-	3,529
	Total Funding for L4 Approach, $K	3,180	2,810	2,680	2,200	2,970	-	13,840

WBS		Fiscal Year					
2	ITAS						
2.3	Ultra-light weight vehicle technologies for HALE	05	06	07	08	09	10
2.3.2	Competing lightweight airframe and subsystem concepts						
2.3.2.1	Develop and document competing structural concepts (including integrated subsytems) for FY09 & FY14 flights						
2.3.2.2	Complete bench test of selected concepts resulting in xx% reduction in empty weight fraction on scaled model for FY0 flight test						
2.3.2.3	Complete bench test of selected concepts resulting in xx% reduction in empty weight fraction on scaled model for FY1 flight test						
2.3.2.4	Develop and document competing structural concepts (including integrated subsytems) for 15 year capability set						
2.3.2.5	Complete WT test of selected concept resulting in xx% reduction in empty weight fraction on scaled model FY14 flight test (over guideline)						

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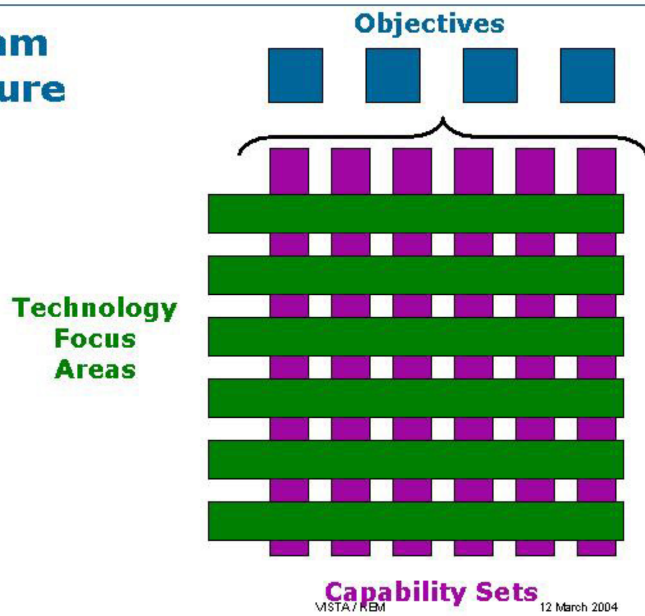
Program Structure



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Aeronautics Theme Objectives for the Public Good

Protect the Environment
Protect local and global environmental quality by reducing aircraft noise and emissions.

Increase Mobility
Enable more people and goods to travel faster and farther with fewer delays

Explore New Aerospace Missions
Pioneer novel aerospace concepts and technologies to support science missions and terrestrial and space applications

Partnerships for National Security
Enhance the Nation's security through aeronautical partnerships with DOD, DHS, and other U.S. or international government agencies

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6 Vehicle Sectors

Associate Program Manager for VISTA
Bob McKinley
Teresa Kline

Subsonic Transports
Fay Collier & Bob Plencner

Supersonic Aircraft
Peter Coen & Mary Jo Long-Davis

Rotorcraft
Gloria Yamauchi

Uninhabited Air Vehicles
Larry Camacho

Personal Air Vehicles
Mark Moore

Extreme STOL
John Zuk

7 Projects

Quiet Aircraft Technology (QAT)
Mike Marcolini & Linda Bangert

Ultra-Efficient Engine Technology (UEET)
Gary Seng (acting) & Mary Jo Long-Davis (acting)

Efficient Aerodynamics Shapes and Integration (EASI)
Jim Pittman & Dave Hahne

Integrated Tailored AeroStructures (ITAS)
Long Yip & Jeffrey Jordan

Autonomous Robust Avionics (AuRA)
Jim Burley & Dave Richwine (acting)

Low-Emission Alternative Power (LEAP)
Anita Liang (acting) & Pete McCallum

Flight & Systems Demonstration (F&SD)
Dave McBride & Eddie Zavala

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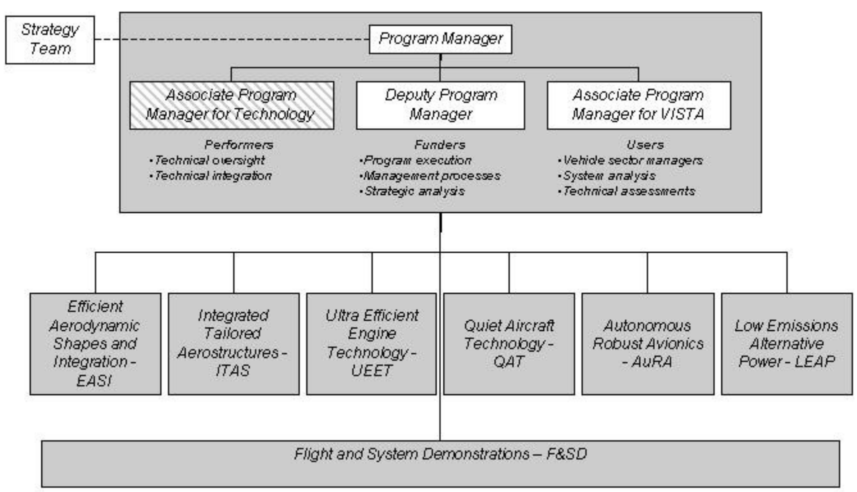
Vehicle Systems Organizational Chart



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So What?

- **The Vehicle Systems Program is replanned and restructured**
  - New goals, new focus, new structure, new processes
- **Industry, academia and other government agencies have been a key part of the new Program vector**
  - Via workshops, sharing of expert opinion and existing analyses
  - Peer review
- **Vehicle Systems is now executing fewer activities with more specific, capability-driven deliverables**
  - Direct linkage between work activities, Program goals, Agency Objectives, and National Needs

Future Vehicle Capability Sets

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QuEST

Quiet, Efficient Subsonic Transport

(DRAFT Metrics: 65 dB contour <55 sqmi, -25% CO_2, -70% NO_x, 300 passenger or equivalent)

Low-noise, low-emission, highly efficient transport aircraft

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15-year Technology Goal Set

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Subsonic Transport Sector

Sector Technology Area	Goal
• Lift to Drag Ratio	25
• Empty Weight / Payload Weight Ratio	3.8
• TSFC (installed @ cruise)	0.51
• Engine T/W (installed)	5.75
• Community Noise (EPNdB) (-20dB at each of 3 certification points)	SOA – 20
• Noise Footprint (sqmi, 65 dBA single event)	55
• Emissions (kg NO_x /LTO)	27

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HeVSTOL

Heavy-Lift Vertical/Short Takeoff and Landing

120-passenger, 1200nm, V/STOL

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HALE ROA

High Altitude Long Endurance Remotely Operated Aircraft

14-day endurance, 60-70K ft ops, 400 lb payload

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S⁴T
Silent Small SuperSonic Transport

(DRAFT Metrics: <0.5 psf boom overpressure, M_{cr} >1.6, 6500' TOFL, 8-10 passengers or equivalent)

Overland supercruise with acceptable sonic boom

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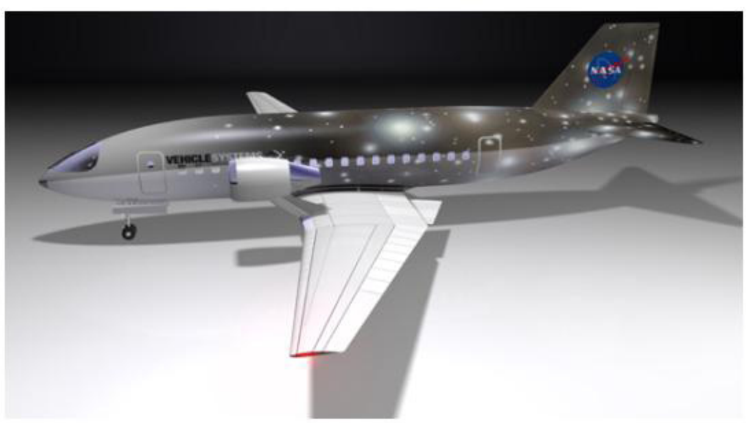
ExSTOL
Extreme Short TakeOff and Landing Transport



<2000' TOFL, M=0.8 cruise, quiet, V_{mceo} ~50kts

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EQuiPT

Easy-to-use, Quiet Personal Transportation

-30 dB vs. SOA, auto-like ease of use, $75K

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Circulation Control as a Potential Solution for the Capability Sets

- **Circulation control (CC) may be applicable to all of the Vehicle Sectors**
  - ESTOL: Obvious connection (see following chart)
  - PAV: Strong connection (see 2nd chart following)
  - SSA: Not so obvious, but also strong (see 3rd chart following)
  - ST: May need CC to achieve noise goals
  - Rotorcraft: Use CC on rotors?
  - UAV: Possible use of CC in the far-term, depending on the mission requirements
- **VISTA team will be working with technologists to define the potential contribution of CC and related technologies towards meeting the Program goals.**

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ESTOL and Circulation Control

- **ESTOL: Investment in short-field capability is a top priority**
- **Key is simultaneous achievement of all elements of the capability set**
  - $\leq$ 2000’ LTO (landing/takeoff) field length (related goal of C_{Lmax} = 10)
  - Cruise at M=0.8
  - Quieter than other small transports
  - Engine out control at ~50 knots
- **Current state of the art (SOA) enables 2 or perhaps 3 of the elements at one time**
- **CC is a strong candidate for enabling the whole set**

PAV and Circulation Control

- **PAV: Investment in high-lift technology is a 2nd priority**
  - First priorities are for ease of use and noise
- **Cruise-sized wing**
  - LTO wing size drives current general aviation aircraft
    - Compromise between V_{stall} and V_{cruise}
  - Optimum is cruise-sized wing with proper C_L (~3) for V_{stall} < 61knots
- **V/STOL**
  - CC may be enabling to this class of vehicle
  - CC Nacelle
- **CC is a strong candidate for enabling PAV capabilities**

SSA and Circulation Control

- **SSA: Investment in high-lift technology is a 2nd priority**
  - First priority is establishing low-boom boundary conditions
- **Low-Boom vs. All Other Performance Issues**
  - Existing low-boom designs need loooong runways
    - i.e., Edwards AFB long
  - Desired LTO field length is $\leq$ 6500 ft.
    - LTO-sized wing is not suitable for low-boom (wrong lift distribution)
  - LTO noise is a show-stopper
    - Remember HSR?
- **CC may enable a boom-sized wing that also meets the LTO noise and field length requirements**

Next Steps

- Finish detailed connection of plans to GOTChA's and Roadmaps
  - Finish FY05 Project Plans
- Begin Baseline Vehicle Assessments and Scenario-Based Analysis
  - Define L1 Milestones based on Sector capabilities and relation to Theme Objectives
  - Solicit technology plans from every sub-project in every project
  - Execute Vehicle Sector Analysis Plan
- VS Annual Meeting on 11-13 May, Atlanta, GA
- VS Program Non-Advocates Review on 21-24 June, Alexandria, VA
- Begin VS Program execution on 1 October 2004
- Refine the plan annually
  - Solicit industry/academia/government input
  - Tweak the plan
  - Execute

Points of Contact

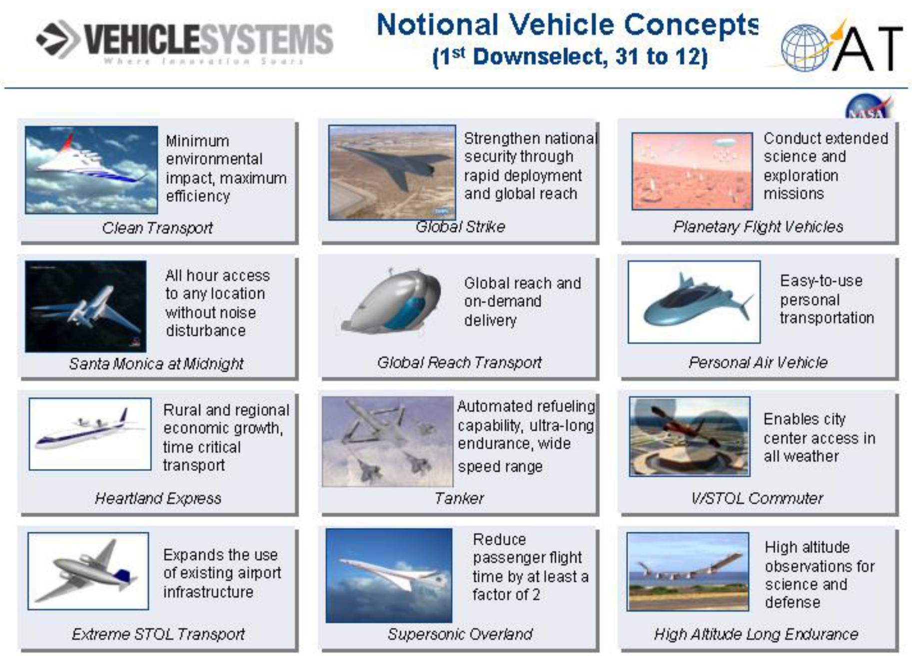
- Vehicle Sectors Managers
  - ESTOL: John Zuk (jzuk@mail.arc.nasa.gov)
  - PAV: Mark Moore (mark.d.moore@nasa.gov)
  - Rotorcraft: Gloria Yamauchi (gloria.k.yamauchi@nasa.gov)
  - SSA: Peter Coen (peter.g.coen@nasa.gov) & Mary Jo Long-Davis (mary.j.long-davis@nasa.gov)
  - ST: Fay Collier (fayette.s.collier@nasa.gov) & Bob Plencner (robert.m.plencner@nasa.gov)
  - UAV: Larry Camacho (lawrence.camacho@mail.dfrc.nasa.gov)
- Project Managers
  - AuRA: Jim Burley (james.r.burley@nasa.gov)
  - EASI: Jim Pittman (james.l.pittman@nasa.gov)
  - F&SD: David McBride (david.d.mcbride@nasa.gov)
  - ITAS: Long Yip (long.p.yip@nasa.gov)
  - LEAP: Anita Liang (acting) (anita.d.liang@nasa.gov)
  - QAT: Mike Marcolini (michael.a.marcolini@nasa.gov)
  - UEET: Gary Seng (acting) (gary.t.seng@nasa.gov)

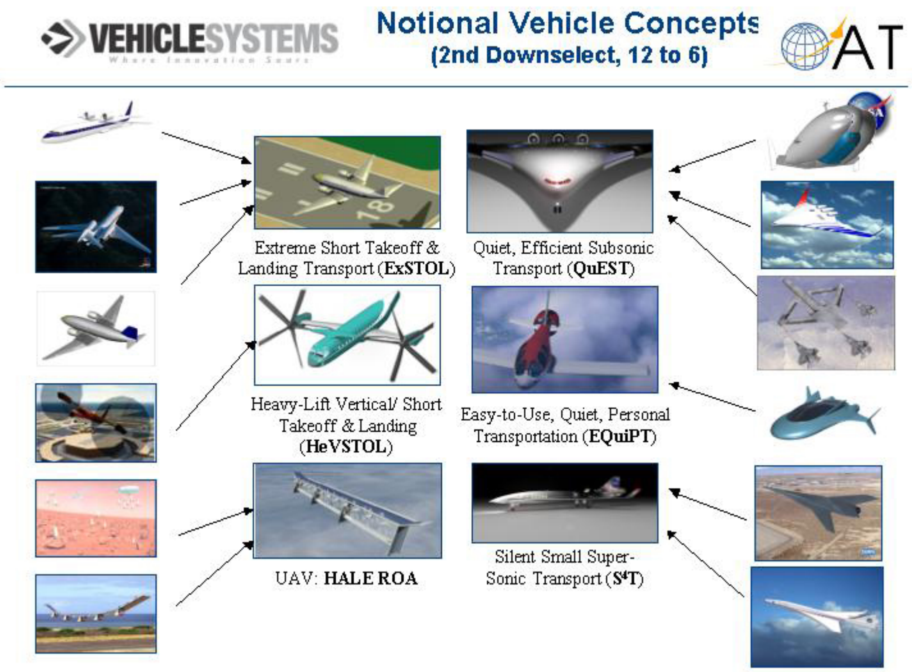
Backup Charts

Sectors & Capabilities: History

- **Vehicle capability sets and notional concepts**
  - Reno workshop, January 2003
  - Industry/Academia/Government teams brainstormed to come up with 31 vehicles and associated capability sets (1st chart following) and 178 technology challenges
  - NASA VSM's distilled to 12 capability sets, 15 common tech challenges (2nd chart following)
- **Roadmaps to capability sets**
  - Phoenix workshop, April/May 2003
  - Industry/Academia/Government teams developed roadmaps from rough GOTChA charts for the 12 capability sets and 15 common tech challenges
- **Today**
  - 6 sectors and capability sets distilled from the Phoenix work and subsequent prioritization efforts (3rd chart following)

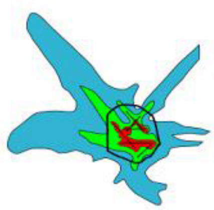

VEHICLESYSTEMS
Notional Vehicle Concepts
(Reno Workshop, 31 Concepts)
AT
ST
SSA
RIA
PAV
UAV
NASA


VEHICLESYSTEMS
Notional Vehicle Concepts
(1st Downselect, 31 to 12)
AT
Minimum environmental impact, maximum efficiency
Clean Transport
Strengthen national security through rapid deployment and global reach
Global Strike
Conduct extended science and exploration missions
Planetary Flight Vehicles
All hour access to any location without noise disturbance
Santa Monica at Midnight
Global reach and on-demand delivery
Global Reach Transport
Easy-to-use personal transportation
Personal Air Vehicle
Rural and regional economic growth, time critical transport
Heartland Express
Automated refueling capability, ultra-long endurance, wide speed range
Tanker
Enables city center access in all weather
V/STOL Commuter
Expands the use of existing airport infrastructure
Extreme STOL Transport
Reduce passenger flight time by at least a factor of 2
Supersonic Overland
High altitude observations for science and defense
High Altitude Long Endurance


VEHICLESYSTEMS
Notional Vehicle Concepts
(2nd Downselect, 12 to 6)
Extreme Short Takeoff & Landing Transport (ExSTOL)
Quiet, Efficient Subsonic Transport (QuEST)
Heavy-Lift Vertical/ Short Takeoff & Landing (HeVSTOL)
Easy-to-Use, Quiet, Personal Transportation (EQuiPT)
UAV: HALE ROA
Silent Small Super-Sonic Transport (S4T)

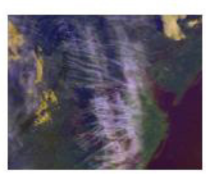
Theme Objectives

Environmentally Friendly Aircraft



Noise within airport boundaries
Constrain objectionable noise to within airport boundaries

Smog-free
Minimize the contribution of air vehicles to the production of smog



No impact on global climate
Minimize the impact of air vehicles on global climate

VEHICLE SYSTEMS
Where Innovation Soars

AERONAUTICS enterprise

Aircraft for Public Mobility

More Convenient
Expand access to aviation to more locations and make it available on-demand

More Affordable
Make air travel available to the entire population

...without compromising safety

Faster

Increase the speed of air travel

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VEHICLE SYSTEMS
Where Innovation Soars

AERONAUTICS enterprise

Air Vehicles for New Missions

Science platforms
Develop innovative air vehicles for science missions in the earth's atmosphere and beyond

Hazardous environments
Enable uninhabited air vehicles to fly in hazardous environments

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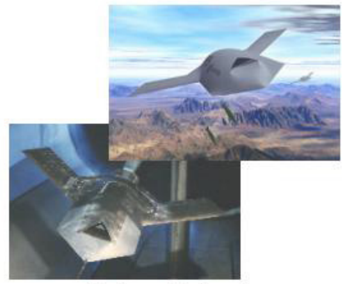
Superior Air Power

Technological superiority

Cooperatively develop technologies that enable air superiority

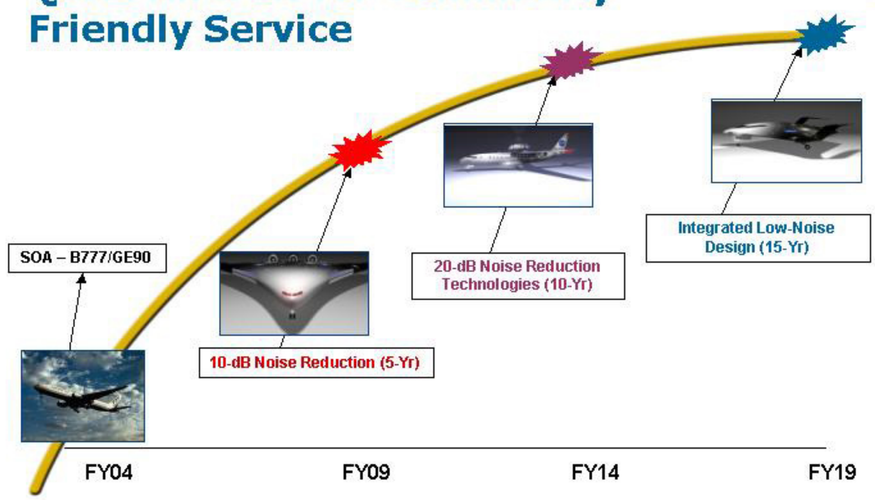


Partners in freedom

Support the development of advanced military aircraft

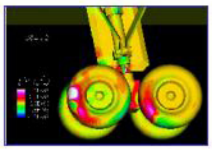
Projects

Quiet Aircraft for Community Friendly Service

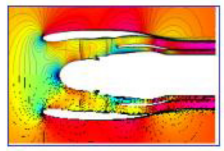


QAT
Quiet Aircraft Technology

Aircraft Operations



Airframe Noise Reduction

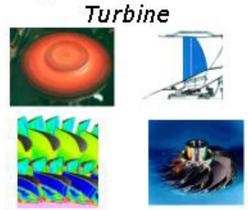


Source Noise Reduction

UEET
Ultra Efficient Engine Technology

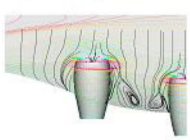
70%LTO NOx Combustor

Highly Loaded, Low Weight Compressor & Turbine



UEET Integration and Demonstration

Highly Integrated Inlet



Intelligent Propulsion System Foundation Technologies

VEHICLE SYSTEMS
Where Innovation Soars

5-year Project

AERONAUTICS enterprise

AuRA
Autonomous Robust Avionics

Integrated Vehicle Systems Management

Adaptive Optimal Flight Controls

Autonomous Vehicle Operations

Intelligent Mission Management

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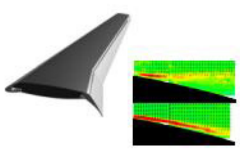
VEHICLE SYSTEMS
Where Innovation Soars

5-year Project

AERONAUTICS enterprise

ITAS
Integrated Tailored Aerostructures

Actively Tailored High-Lift Systems



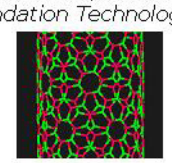
Adaptive, Ultra-Lightweight Airframe Systems

Highly-loaded, Lightweight Structures

Integrated Tailored VTOL Concepts

Planetary Vehicles

Weight Reduction & Community Access Foundation Technologies



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VEHICLE SYSTEMS
Where Innovation Soars

5-year Project

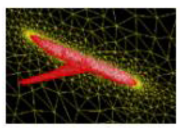
AERONAUTICS enterprise

EASI
Efficient Aerodynamic Shapes and Integration

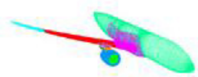
Reduced Fuel Burn Transport Wing

Sub-Scale Efficient Heavy Lift VTOL Aeromechanics Demonstration

Variable Fidelity Conceptual Design Tool Development & Validation



Computational Methods for Flight Performance Prediction



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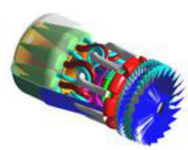
VEHICLE SYSTEMS
Where Innovation Soars

5-year Project

AERONAUTICS enterprise

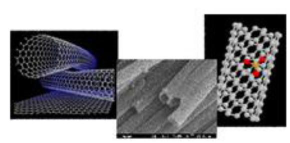
LEAP
Low Emissions Alternative Power

Aircraft Fuel Cell Power Systems



Constant Volume Combustion Cycle Engine

University Research, Engineering & Technology Institute (URETI)



Alternate Fuel Foundation Technologies

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Current Demonstrations

F&SD

Flight and Systems Demonstrations

Intelligent Flight Control Systems

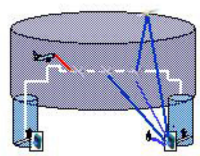
Advanced Aeroelastic Wing

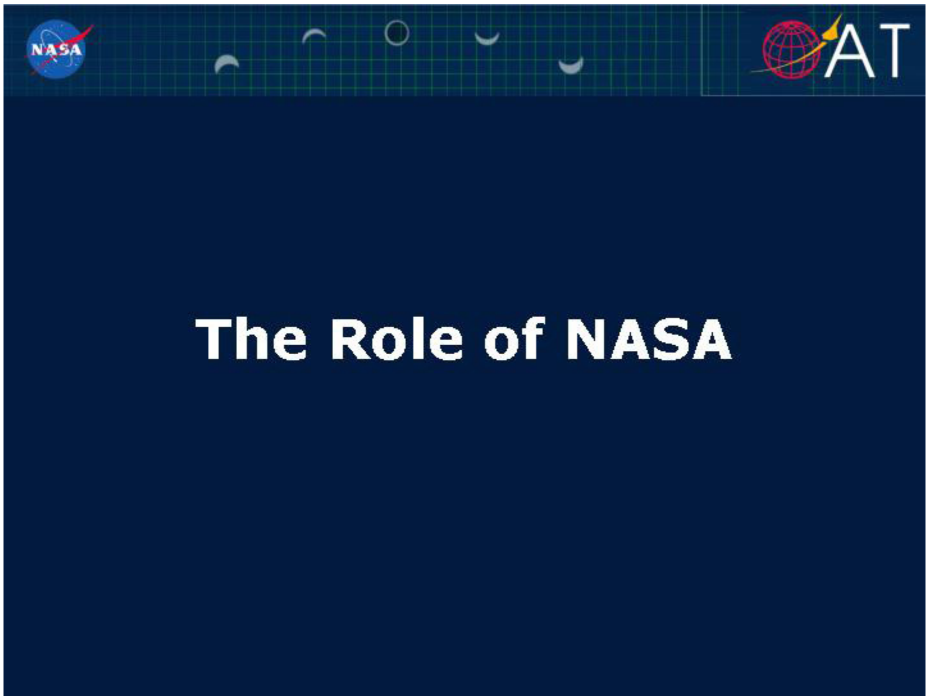
Flight Research Productivity Tools

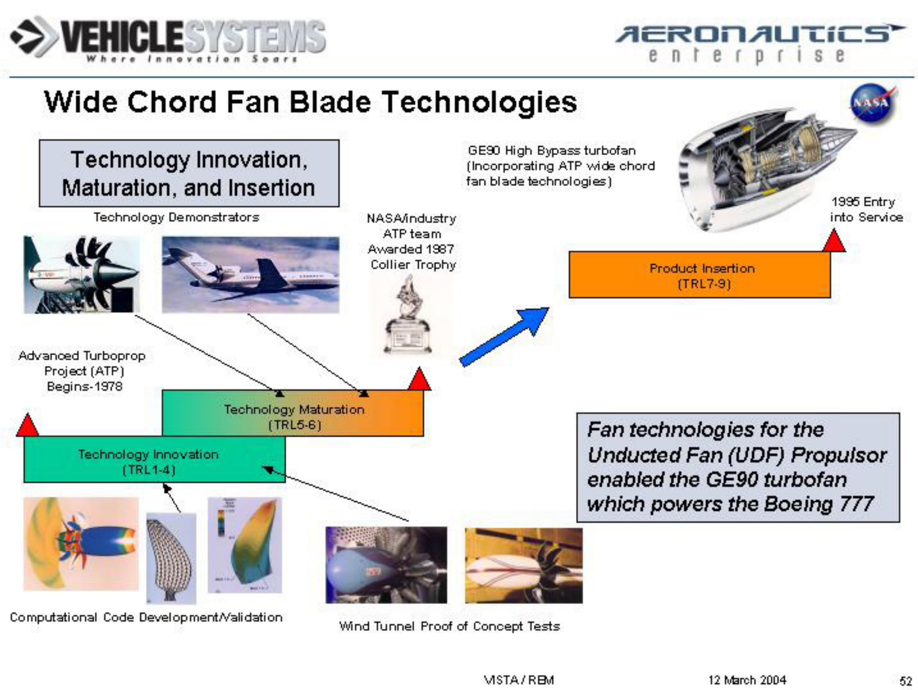
HALE ROA Capabilities

Earth Science Capability Demos

HALE ROA in the NAS




The Role of NASA


VEHICLE SYSTEMS
Where Innovation Soars
AERONAUTICS enterprise
Wide Chord Fan Blade Technologies
Technology Innovation, Maturation, and Insertion
Technology Demonstrators
NASA/industry ATP team Awarded 1987 Collier Trophy
GE90 High Bypass turbofan (Incorporating ATP wide chord fan blade technologies)
1995 Entry into Service
Product Insertion (TRL7-9)
Advanced Turboprop Project (ATP) Begins-1978
Technology Maturation (TRL5-6)
Technology Innovation (TRL1-4)
Fan technologies for the Unducted Fan (UDF) Propulsor enabled the GE90 turbofan which powers the Boeing 777
Computational Code Development/Validation
Wind Tunnel Proof of Concept Tests
VISTA / REM
12 March 2004
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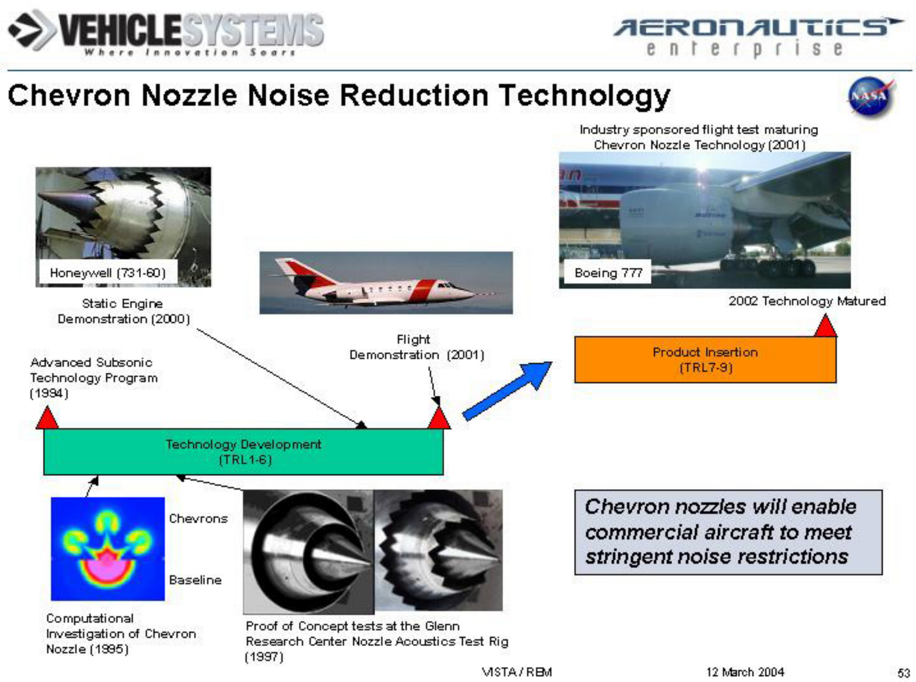
VEHICLE SYSTEMS
Where Innovation Soars
AERONAUTICS enterprise
Chevron Nozzle Noise Reduction Technology
Industry sponsored flight test maturing Chevron Nozzle Technology (2001)
Honeywell (731-60)
Boeing 777
Static Engine Demonstration (2000)
2002 Technology Matured
Flight Demonstration (2001)
Product Insertion (TRL7-9)
Advanced Subsonic Technology Program (1994)
Technology Development (TRL1-6)
Chevrons
Baseline
Chevron nozzles will enable commercial aircraft to meet stringent noise restrictions
Computational Investigation of Chevron Nozzle (1995)
Proof of Concept tests at the Glenn Research Center Nozzle Acoustics Test Rig (1997)
VISTA / RBM
12 March 2004
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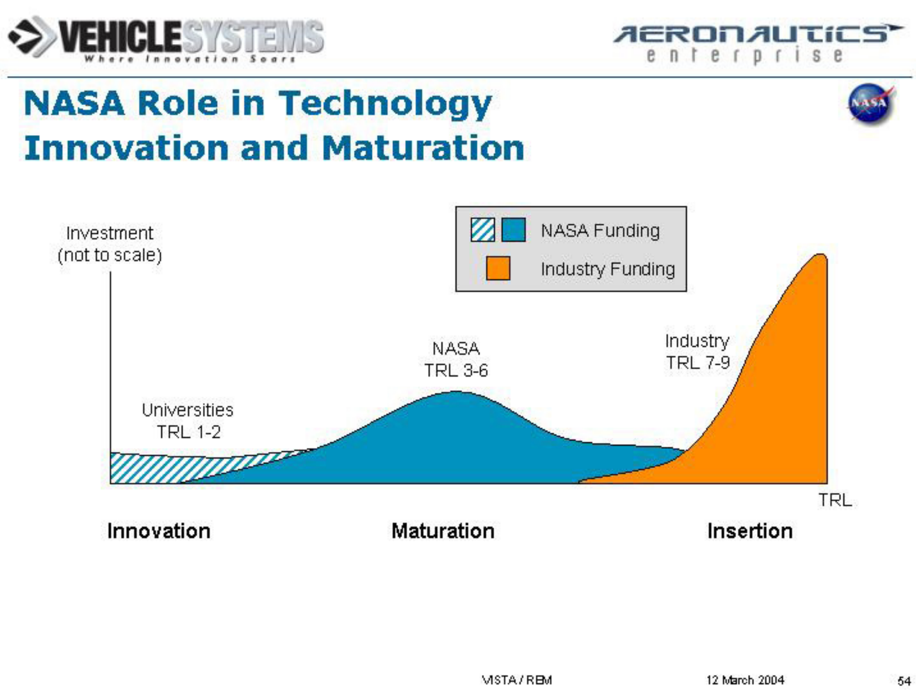
VEHICLE SYSTEMS
Where Innovation Soars
AERONAUTICS enterprise
NASA Role in Technology Innovation and Maturation
Investment (not to scale)
NASA Funding
Industry Funding
NASA TRL 3-6
Industry TRL 7-9
Universities TRL 1-2
TRL
Innovation
Maturation
Insertion
VISTA / RBM
12 March 2004
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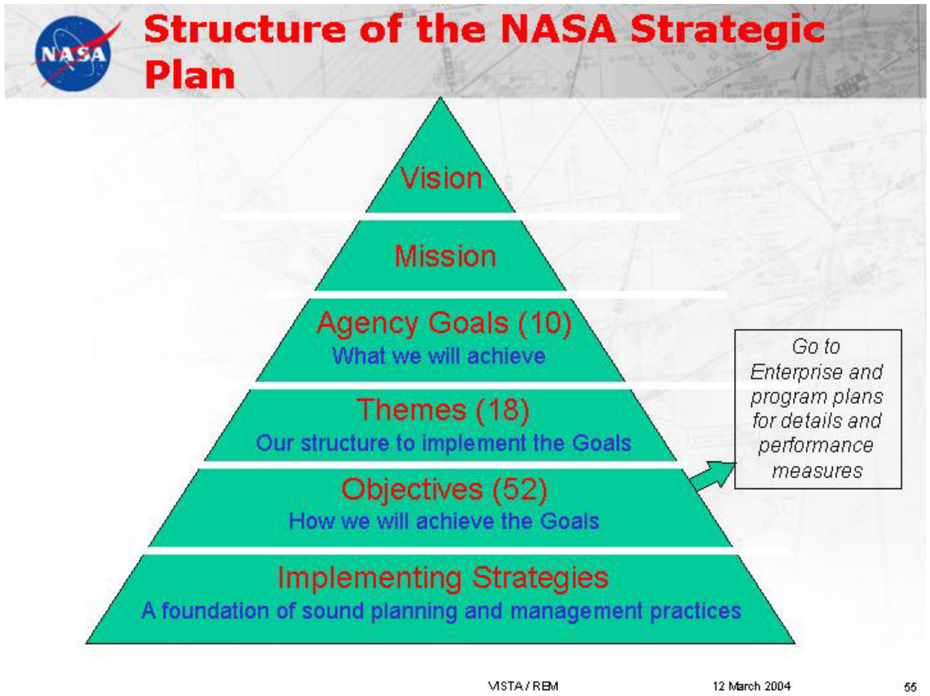
Structure of the NASA Strategic Plan
Vision
Mission
Agency Goals (10)
What we will achieve
Themes (18)
Our structure to implement the Goals
Objectives (52)
How we will achieve the Goals
Implementing Strategies
A foundation of sound planning and management practices
Go to Enterprise and program plans for details and performance measures
VISTA / REM
12 March 2004
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