NASA ULTRA EFFICIENT ENGINE TECHNOLOGY PROJECT OVERVIEW

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Glenn Research Center
Cleveland, Ohio

NASA Ultra Efficient Engine Technology Project Overview

Enabling Technologies for 21st Century Turbine Engines

Joe Shaw
UEET Project Manager

Catherine Peddie
UEET Assistant Project Manager
Outline

- Overview of current UEET Project
- Re-invention of UEET as part of the Vehicle Systems Program
Current UEET Project
The NASA Mission

To understand and protect our home planet
To explore the Universe and search for life
To inspire the next generation of explorers

... as only NASA can.
The UEET Program will develop and transfer to the U. S. industry critical gas turbine engine technologies which will contribute to “enabling a safe, secure, and environmentally friendly air transportation system”.
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
Revolutionize Aviation Goal     Emissions Objective

Reduce emissions of future aircraft by a factor of three within 10 years (2007), and by a factor of five within 20 years.

NASA Three Pillars for Success-1997

Reduce NOx emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NOx as the baseline). Reduce CO2 emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).

NASA Aerospace Technology Enterprise Strategic Plan-2000

UEET will be the responsible propulsion program for delivering on this objective!
Vision: Develop and hand off revolutionary turbine engine propulsion technologies that will enable future generation vehicles over a wide range of flight speeds.

Goals:

Propulsion technologies to enable increases in system efficiency and, therefore, fuel burn reductions of up to 15% (equivalent reductions in CO₂)

Combustor technologies (configuration and materials) which will enable reductions in LTO* NOₓ of 70% relative to 1996 ICAO standards. * LTO - Landing/Take-off
Develop and hand off revolutionary propulsion turbine engine technologies that will enable future generation vehicles over a wide range of flight speeds.

We support the vision and are committed to the success of NASA’s Ultra Efficient Engine Technology (UEET) Project.

William Koop, Air Force Research Laboratory
Gerald Brines, Allison-Rolls Royce
Mahmood Naimi, Boeing Commercial Airplane Company
Fred Krause, General Electric Aircraft Engines
Dimitri Mavris, Georgia Tech
11m Conners, Gulfstream
Vinod Nangia, Honeywell
Tom Hartmann, Lockheed-Martin
Robert J. Shaw, NASA Glenn Research Center
Robert D. Southwick, Pratt & Whitney
Scott Cruzen, Williams International

Last Update - April 2003
Baseline Vehicles for UEET Technology Application Studies

**Subsonic**
- **300 PAX**
  - Large Subsonic Transport
- **50 PAX**
  - Regional Jet Transport
- **500-600 PAX**
  - Blended Wing Body (BWB)

**Supersonic**
- **300 PAX**
  - High Speed Civil Transport (HSCT)
- **10 PAX**
  - Supersonic Business Jet (SBJ)

**Hypersonic**
- **Access-to-Space/High Mach Platform**

**Commercial Vehicles**
- **4 PAX**
  - General Aviation Aircraft (GA)
  - Military Transport (C-17)
  - Unmanned Aerial Vehicle (UAV)

**Non-Commercial Vehicles**
- **These vehicles drive the technology investment strategy**
- **These vehicles determine the technology synergies**
# Program Technical Objectives

## CO\textsubscript{2} Goal
- **Goal**: 15% fuel burn reduction for large subsonic aircraft
- **Minimum Success Criteria**: 12% fuel burn reduction for large subsonic aircraft

## NO\textsubscript{x} Goal
- **Goal**: 70% NO\textsubscript{x} reduction (below ICAO 96) for subsonic (large/ regional) combustors over the LTO cycle
- **Minimum Success Criteria**: 65% NO\textsubscript{x} reduction (below ICAO 96) for subsonic (large/ regional) combustors over the LTO cycle
**NASA’s Technology Readiness Level (TRL) Scale**

<table>
<thead>
<tr>
<th>TRL</th>
<th>General NASA Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basic principles observed and reported</td>
</tr>
<tr>
<td>2</td>
<td>Technology concept and/or application formulated (candidate selected)</td>
</tr>
<tr>
<td>3</td>
<td>Analytical and experimental critical function, or characteristic proof-of-concept</td>
</tr>
<tr>
<td>4</td>
<td>Component and/or breadboard test in a laboratory environment</td>
</tr>
<tr>
<td>5</td>
<td>Component and/or breadboard verification in a relevant environment</td>
</tr>
<tr>
<td>6</td>
<td>System/subsystem model or prototype demonstrated/validated in a relevant environment</td>
</tr>
<tr>
<td>7</td>
<td>System prototype demonstrated in flight environment</td>
</tr>
<tr>
<td>8</td>
<td>Actual system completed and “flight qualified” through test and demonstration</td>
</tr>
<tr>
<td>9</td>
<td>Actual system “flight proven” on operational flight</td>
</tr>
</tbody>
</table>
UEET Elements

Emissions Reduction

Highly Loaded Turbomachinery
GRC Lead

Materials and Structures for High Performance

Propulsion-Airframe Integration
LaRC Lead

Propulsion Systems Integration and Assessment
GRC Lead

Integrated Component Technology Demonstrations
GRC Lead

Intelligent Propulsion Controls
GRC Lead

Ultra Efficient Engine Technology
NASA/CP—2004-21263/VOL1
Selected Technical Highlights

Ultra Efficient Engine Technology

70% LTO NOx combustor sector tests

2 stage POC compressor rig design

Rig/engine tests to measure particulates, aerosol emissions

CMC combustor liner for engine test

Active flow control to reduce inlet distortion

Turbomachinery disk material temperature limit
The UEET “Roadmap”

**2015 “Ultimate” Turbine Engine Systems**
- Emissions
- Fuel burn
- Weight
- Noise
- Safety
- Reliability

**Integrated component technology validations**
(in *cost-sharing partnership* with other government agencies and/or industry)

**Periodic assessments/rebalancing of portfolio**

**UEET Technologies**
- Components
- Materials and structures
- Intelligent propulsion controls
- Propulsion-airframe integration
The Path to Re Invention of the UEET Project
Aeronautics Technology – Three Integrated Programs

Airspace Systems

Aviation Safety & Security

Vehicle Systems

Airspace Capability

Cost

Environment

Safety/Security

Vehicle Capability
Aeronautics Theme Objectives for the Public Good

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

**Increase Mobility**
Enable more people and goods to travel faster and farther, anywhere, anytime with fewer delays

**Explore New Aerospace Missions**
Pioneer novel aerospace concepts to support earth and space science missions

**Support National Security**
Leverage NASA aeronautics technology investments in partnership with DOD to support their role of protecting the Nation
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
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

Faster
Increase the speed of air travel

...without compromising safety
### Innovative Vehicle Concepts to Identify Key Technology Requirements

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Clean Transport</strong></td>
<td>Minimum environmental impact, maximum efficiency</td>
</tr>
<tr>
<td><strong>Global Strike</strong></td>
<td>Strengthen national security through rapid deployment and global reach</td>
</tr>
<tr>
<td><strong>Planetary Flight Vehicles</strong></td>
<td>Conduct extended science and exploration missions</td>
</tr>
<tr>
<td><strong>Santa Monica at Midnight</strong></td>
<td>All hour access to any location without noise disturbance</td>
</tr>
<tr>
<td><strong>Global Reach Transport</strong></td>
<td>Global reach and on-demand delivery</td>
</tr>
<tr>
<td><strong>Personal Air Vehicle</strong></td>
<td>Rural, regional, and intra-urban transportation</td>
</tr>
<tr>
<td><strong>Heartland Express</strong></td>
<td>Rural and regional economic growth, time critical transport</td>
</tr>
<tr>
<td><strong>Tanker</strong></td>
<td>Automated refueling capability, ultra-long endurance, wide speed range</td>
</tr>
<tr>
<td><strong>V/STOL Commuter</strong></td>
<td>Enables city center access in all weather</td>
</tr>
<tr>
<td><strong>Extreme STOL Transport</strong></td>
<td>Expands the use of existing airport infrastructure</td>
</tr>
<tr>
<td><strong>Supersonic Overland</strong></td>
<td>Reduce passenger flight time by at least a factor of 2</td>
</tr>
<tr>
<td><strong>High Altitude Long Endurance</strong></td>
<td>High altitude observations for science and defense</td>
</tr>
</tbody>
</table>
Project Evolution within Replanned Vehicle Systems Strategic Focus Areas

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Years</th>
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<tbody>
<tr>
<td>Quiet Aircraft for Community Friendly Service</td>
<td>04</td>
</tr>
<tr>
<td>QAT</td>
<td>05</td>
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<tr>
<td>4x Noise Reduction</td>
<td>06</td>
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<tr>
<td>4X Demo (F&amp;SD)</td>
<td>07</td>
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<tr>
<td>Design for Quiet</td>
<td>08</td>
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<tr>
<td>Integrated Quiet, Efficient Aircraft Design</td>
<td>09</td>
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<tr>
<td>Environmentally Friendly, Clean Burning Engines</td>
<td>10</td>
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<tr>
<td>UEET</td>
<td>11</td>
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<tr>
<td>UEET Demo (F&amp;SD)</td>
<td>12</td>
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<tr>
<td>Intelligent Propulsion Systems</td>
<td>13</td>
</tr>
<tr>
<td>Integrated Flight/Propulsion Intelligence Demo (F&amp;SD)</td>
<td>14</td>
</tr>
<tr>
<td>Autonomous Propulsion Systems</td>
<td>15</td>
</tr>
<tr>
<td>Smart Aircraft and Autonomous Control</td>
<td>16</td>
</tr>
<tr>
<td>IFCS-GenII (F&amp;SD)</td>
<td>17</td>
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<tr>
<td>IFCS - Adaptive Optimal FCS Demo (F&amp;SD)</td>
<td>18</td>
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<tr>
<td>UAV in the NAS Step 1 and 2 (FSD)</td>
<td>19</td>
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<tr>
<td>Multi-UAV Command, Control, Communications (F&amp;SD)</td>
<td>20</td>
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<tr>
<td>Autonomous Robust Avionics</td>
<td>21</td>
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<tr>
<td>AuRA Flight Demo (F&amp;SD)</td>
<td>22</td>
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<tr>
<td>Sentient Air Vehicle</td>
<td>23</td>
</tr>
<tr>
<td>Autonomous Certification Methods</td>
<td>24</td>
</tr>
<tr>
<td>Autonomous Transport Technology</td>
<td>25</td>
</tr>
</tbody>
</table>
Factors Driving Change

- Administration/OMB drivers that are not going away
  - Be more competitive (outhouse and in house) to get “best product”
  - Right size the NASA institution (people and facilities)
  - Proper role of government programs in aerospace R&D food chain

- Increasing stress on Federal budget
  - Growing Federal deficits for foreseeable future
  - Administration priorities (Homeland security and anti terrorism)
  - Aerospace priorities (National and Agency)
Opportunities

Opportunity to:

- significantly strengthen UEET in the eyes of our customers/partners/stakeholders

-- increase the support of key decision makers for UEET

- make major technology impacts on next generation gas turbine engine propulsion systems

- carry our relationship with DoD (IHPTET/VAATE) to the next level

- forge a partnership with NAI, NGLT

- be a leader in developing a new NASA/other government agencies/industry/university partnership model for aerospace R&T
How do we do it?
Vehicle Systems Program Structure

**External Groups**
- Red Team
  - ATAC/VSWG
  - NRC/AESEB

**Vehicle Systems**
- (HQ)

**Strategy Team**
- (One representative per center)

**Vehicle Integration, Strategy, and Technical Analysis (VISTA)**

**Flight and System Demonstrations (DFRC)**

**Efficient Aerodynamic Shapes and Integration - EASI (LaRC)**

**Integrated Tailored Aerostructures - ITAS (LaRC)**

**Ultra Efficient Engine Technology - UEET (GRC)**

**Quiet Aircraft Technology - QAT (LaRC/GRC)**

**Autonomous Robust Avionics - AuRA (LaRC/DFRC)**

**Low Emissions Alternative Power - LEAP (GRC)**

**UEETnew will:**
- Be a TRL 1-6 project.
- The only project in the Vehicle Systems Program focused entirely on turbine engine propulsion systems.
- Invest approximately 20% of resources into developing a technology foundation for the follow on project.
The FY04 Challenge

- UEET Program/Project (FY04 plans)
- Propulsion & Power Program/Project (Turbine engine portion)
- UEETnew (FY04-07)
Vision: Develop and hand off revolutionary turbine engine propulsion technologies that will enable future generation vehicles over a wide range of flight speeds.

Goals:

Propulsion technologies to enable increases in system efficiency and, therefore, fuel burn reductions of up to 15% (equivalent reductions in CO₂)

Combustor technologies (configuration and materials) which will enable reductions in LTO* NOₓ of 70% relative to 1996 ICAO standards.

These will remain the same!

* LTO - Landing/Take-off
UEETnew “Characteristics”

- UEETnew will focus on technologies for subsonic and supersonic commercial systems. The subsonic systems will be regional jets though large wide bodies. The supersonic systems will be SSBJ through commercial transports (10-100 PAX).

- UEETnew will do selected rotorcraft technologies that are dual use technologies which benefit our prime customer base.

- UEETnew will continue to emphasize partnership efforts with DoD that emphasize collaborative efforts to develop dual use technologies.

- UEETnew will use systems studies results as a prime factor in prioritizing and selecting technology efforts. Expert opinion will be employed wherever appropriate (e.g. areas where systems studies cannot currently model technology impacts).
Critical aspects of UEET Re-invention

Lower TRL efforts
- Lay foundation for follow on project - Intelligent Propulsion Systems
- All efforts openly competed and selected
- Partnerships encouraged

Higher TRL efforts
- Contribution to achievement of UEET goals
- Appropriate for NASA investment
- Possible dual use technology with partnering with DoD
- Up front commitments by cost sharing partner
  - Cost sharing amount and type
  - Technology transition/insertion plan
  - Approach to utilizing NASA personnel, facilities
UEETnew Sub Project Structure

70% LTONOx
HLLWCT$^1$
HI$^2$
I&D$^3$
IPSFT$^4$

Joe Shaw
Cathy Peddie

John Rohde lead
Carol Ginty lead
Mile Watts lead
Mary Jo Long-Davis lead
Carolyn Mercer lead

$^1$HLLWCT-Highly Loaded, Low Weight Compressor and Turbine
$^2$Highly Integrated Inlet
$^3$Integration and Demonstration
$^4$Intelligent propulsion System Foundation Technologies
### Approach to Re-inventing UEET

**Ultra Efficient Engine Technology (UEET)**

<table>
<thead>
<tr>
<th>Sub projects</th>
<th>FY04</th>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
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<td>70% LTO NOx Combustor</td>
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<tr>
<td>Highly Loaded Low Weight Compressor &amp; Turbine (HLLWCT)</td>
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<td>FY04</td>
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<tr>
<td>Highly Integrated Inlet (HII)</td>
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<td>Intelligent Propulsion System Foundation Technologies (IPSFT)</td>
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**Year of Transition**

**Technology evaluations/selections/terminations**

- **FY04**
- **FY05**
- **FY06**
- **FY07**
Approach to Re inventing UEET-Lower TRL

Ultra Efficient Engine Technology

Sub projects | IPS workshops | FY04 | NRA | FY05 | FY06 | IPS | FY07
---|---|---|---|---|---|---|---
70% LTO NOx Combustor | | | | | | |
Highly Loaded Low Weight Compressor&Turbine (HLLWCT) | | | | | | |
Highly Integrated Inlet (HII) | | | | | | |
Intelligent Propulsion System Foundation Technologies (IPSFT) | | | | | | |
Integration&Demonstration (I&D) | | | | | | |

Turbomachinery/materials technologies required for IPS
Inlet/nozzle technologies required for IPS
“Intelligent” propulsion system technologies
Emissions technologies required for IPS
Approach to Re inventing UEET-Lower TRL

Ultra Efficient Engine Technology

<table>
<thead>
<tr>
<th></th>
<th>FY05</th>
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Intelligent Propulsion Systems Project
Developing Higher TRL Technology Partnerships/Transitions

A key part of the new UEET Project will be the selection and transition of UEET technologies with industry/DoD partners to a sufficiently high level so that our partners can use them in future “product designs’ after further technology efforts that go beyond NASA’s charter (i.e. TRL6).

The success of this effort will be one measure as to how UEET will be graded both by the government (e.g. NASA HQ, OMB, Congress) and our partners.

But we must address “corporate welfare” concerns and doing DoD’s job.
Approach to Re inventing UEET-Higher TRL’s

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<tr>
<td>Highly Integrated Inlet (HII)</td>
<td>FY04 Year of Transition</td>
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<td>Intelligent Propulsion System Foundation Technologies (IPSFT)</td>
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Industry proposals ➤ “TRL6” partnership demos

Tech readiness/ transition
Approach to Re inventing UEET-Higher TRL’s

- 70% LTO NOx Combustor
- Highly Loaded Low Weight Compressor&Turbine (HLLWCT)
- Highly Integrated Inlet (HII)
- Intelligent Propulsion System Foundation Technologies (IPSFT)
- Integration&Demonstration (I&D)

Industrial proposals/decisions

- FY04 TRL5 annular rig demos
- FY05 TRL5 materials demos
- FY06
- FY07 TRL6 engine demos (partnerships)

QAT/UEET partnership

Technology transition /insertion
Approach to Re inventing UEET-Higher TRL’s

Some technologies will not require engine tests to successfully transition.
Approach to Re inventing UEET-Higher TRL’s

UEET and F&SD projects will TOGETHER proactively work with the customers to define and conduct the required flight demonstrations!
Some things won’t change!
Baseline Vehicles for UEET Technology Application Studies

**Subsonic**
- **300 PAX**
  - Large Subsonic Transport
- **50 PAX**
  - Regional Jet Transport
- **500-600 PAX**
  - Blended Wing Body (BWB)

**Supersonic**
- **300 PAX**
  - High Speed Civil Transport (HSCT)
- **10 PAX**
  - Supersonic Business Jet (SBJ)

**Hypersonic**
- **Access-to-Space/High Mach Platform**

These vehicles drive the technology investment strategy.

**Commercial Vehicles**

**Non-Commercial Vehicles**
- **4 PAX**
  - General Aviation Aircraft (GA)
  - Military Transport (C-17)
- **Unmanned Aerial Vehicle (UAV)**

These vehicles determine the technology synergies.

These vehicles determine the technology synergies.

NASA/CP—2004-21963/VOL1
Vision

Develop and hand off revolutionary propulsion turbine engine technologies that will enable future generation vehicles over a wide range of flight speeds.

We support the vision and are committed to the success of NASA’s Ultra Efficient Engine Technology (UEET) Project.

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Tim Conners, Gulfstream
Vinod Nangia, Honeywell
Tom Hartmann, Lockheed-Martin
Robert J. Shaw, NASA Glenn Research Center
Robert D. Southwick, Pratt & Whitney
Scott Cruzen, Williams International

Last Update-April 2003
We are committed to working together in partnership to actively seek out opportunities for the transfer of appropriate technologies both into and out of UEET.
Ultra Efficient Engine Technology

Addressing the key national agenda areas that will contribute to 21st Century U. S. aerospace leadership

TEAM

DoD  FAA
NASA  Universities
EPA  Industry

NE

TEAM
Back-up
# Program Status

## October 2003

<table>
<thead>
<tr>
<th>Goal</th>
<th>Status</th>
<th>Remarks</th>
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</table>
| 15% fuel burn reduction for large subsonic | 21% projected for 300 PAX  
25% projected for BWB | Systems studies projections of combined impacts of UEET technologies using available (limited) test data in TRL2-3+ range.  
Initial probabilistic assessment results indicate 94% probability of meeting UEET goal for 300 PAX  
Benefit projections less than previous years’ projections due to technology portfolio changes and refined technology projections. |
| 8% fuel burn reduction for small subsonic, small / large supersonic | 21% for 50 PAX  
18% for 10 PAX SSBJ | |
| 70% NOx reduction (below ICAO 96) for subsonic (large regional) combustors over the LTO cycle | NASA/industry partnership tests of sector configurations (TRL4) give confidence that target objective will be reached.  
79% reduction projected for 300PAX  
83% reduction projected for 50 PAX | Sector tests completed in 4Q of FY03 |
# UEET Level I Milestone Schedule

<table>
<thead>
<tr>
<th>FY</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
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</thead>
<tbody>
<tr>
<td>1.0 Propulsion Systems Integration and Assessment</td>
<td>Preliminary Technology Benefits Assessment</td>
<td>Propulsion System(s) Conceptual Definition</td>
<td>Interim Technology Assessments</td>
<td>Initial High Fidelity System Simulation</td>
<td>Final Technology Assessment</td>
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<td></td>
</tr>
<tr>
<td>2.0 Emissions Reduction</td>
<td>Flame tube Eval's of 70% LTO NOx Concepts</td>
<td>Flow Control Concept(s) Selected for Fan</td>
<td>Low Conductive System Selected</td>
<td>Concepts Selected for 3000°F CMC Mat’l System</td>
<td>CMC Vane Demo.</td>
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<tr>
<td>3.0 Highly Loaded Turbomachinery</td>
<td>Flow Control Concept(s) Selected for Turbine</td>
<td>EPM Alloy Upper Temp. Limit</td>
<td>Ceramic TBC System Selected</td>
<td>Feasibility of UHTC as &gt; 3000°F Structural or Functional Coating Mat’l</td>
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<tr>
<td>4.0 Materials &amp; Structures for High Performance</td>
<td>Ceramic Thermal Barrier Coating (TBC) Concept(s) Selection</td>
<td>Method Downselect</td>
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<td>CMC Vane Demo.</td>
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<tr>
<td>5.0 Propulsion Airframe Integration</td>
<td>Engine Architecture/ Payoff Studies</td>
<td>Eval. of Active Flow Control Concepts</td>
<td></td>
<td>Configuration X Validation</td>
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<td></td>
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<tr>
<td>7.0 Intelligent Propulsion Controls</td>
<td>Active Combustion Control Studies</td>
<td>2200°F CMC Liner Demo</td>
<td>ICTC Plan for Access to Space Engines</td>
<td>Demo Hi Temp (600°C) Wireless Data Communication</td>
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<tr>
<td>8.0 Integrated Component Technology Demonstrations</td>
<td>Integrated Component Technology Demonstrations Plan</td>
<td>ICTD Plan for Small Thrust Class Engines</td>
<td></td>
<td>Demo Hi Temp (600°C) Wireless Data Communication</td>
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</tbody>
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**Notes:**
1. PCA milestones are denoted by 🌟
2. WBS 6.0 reserved for Program Mgmt. functions