NASA/DoD UAPT Research Tasks Organization

Level 1: UAPT Management

- Dr. Jean-Lou Chameau, Senior Research Officer
  - Dr. Ben Zinn, Director
  - Dr. Dimitri Mavris, Co-Director

Level 2: Research Thrust Areas
Level 3: Research Tasks
Level 4: Research Sub-tasks

2.1. Systems Analysis & Tech. Integration — Lead: Mavris, GT

- 2.1.1 VISSTA Environment
- 2.1.2 Analysis Methods for Revolutionary Propulsion Systems
- 2.1.3 UAPT Technology Assessment
- 2.1.4 High Fidelity Design Tool Development*
  - 2.1.4.1 Design-Oriented CFD
  - 2.1.4.2 Life Prediction Tool Development
  - 2.1.4.3 Aeroelastic Response Prediction Tool

2.2. Enabling Technologies — Lead: Williams, OSU

- 2.2.1 Advanced Materials*
  - 2.2.1.1 High Temp. Material
  - 2.2.1.2 Self-healing Mat'ls
- 2.2.2 Actuators*
  - 2.2.2.1 Fluidic Actuators
  - 2.2.2.2 Plasma Aug. Comb.
- 2.2.3 Diagnostics and MEMS Sensors*
  - 2.2.3.1 Wireless MEMS
  - 2.2.3.2 Turbine Diagnostics
- 2.2.4 Nanotechnology*
  - 2.2.4.1 Nanomat'l for E-field Generation
  - 2.2.4.2 Nanometallic Fuel Additives

2.3. Intelligent Engine Systems — Lead: Zinn, GT

- 2.3.1 Compressor Control
- 2.3.2 Emissions Control
- 2.3.3 Turbine Control*
  - 2.3.3.1 Loss Control Via Trailing Edge Injection
  - 2.3.3.2 Adv. Film Cooling Techniques
- 2.3.4 Active Noise Control

2.4. High Performance Components — Lead: Ahuja, GTRI

- 2.4.1 Distributed Exhaust Nozzles
- 2.4.2 Highly Loaded Compressor Blades
- 2.4.3 Low Emission, Quiet, Flameless Combustor

2.5. Advanced Power Technology — Lead: Luongo, FAMU

- 2.5.1 Nanostructured Solid Oxide Fuel Cells
- 2.5.2 Integrated Power Management
- 2.5.3 High-efficiency Superconducting Electric Motors

NASA/DoD UAPT PROGRAM OVERVIEW

URETI on Aeropropulsion and Power Technology
Sponsored by NASA and DoD

2.1: Systems Engineering Analysis and Technology Integration

Dimitri N. Mavris (UAPT Co-Director)
School of Aerospace Engineering

Program Kickoff Meeting
Georgia Tech

Georgia Institute of Technology · The Ohio State University · FAMU Florida A&M University · CWRU

NASA/DoD UAPT Propulsion Technology Taxonomy

2.1.1 VISSTA Environment
2.1.2 Analysis Methods for Revolutionary Propulsion Systems
2.1.3 UAPT Technology System Assessment
2.1.4 High Fidelity Design Tool Development

2.2.1 Advanced Materials
2.2.4 Nanotechnology
2.2.3 Diagnostics and MEMS Sensors

2.5.1 Nanostructured Solid Oxide Fuel Cells
2.5.2 Integrated Power Management
2.5.3 High-efficiency Superconducting Electric Motors

2.4.2 Highly Loaded Compressor Blades

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2.2.2 Actuators

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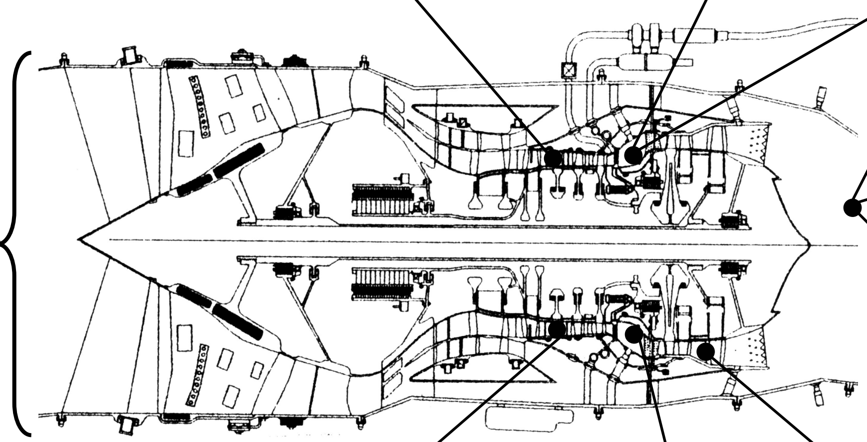

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Task 2.1: Objectives

- Develop methods to facilitate technology evaluation and system integration
  - Integration of disciplinary analysis (lifing, materials, etc.)
  - Framework for evaluating revolutionary technologies
  - Implementation in a single, overarching environment (VISSTA)
- Evaluate system-level impact of technologies developed under NASA/DoD UAPT

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- 2.3.1 **Compressor Control**
- 2.3.2 Emissions Control
- 2.3.3 Turbine Control*
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2.5. Advanced Power Technology Lead: Luongo, FAMU

- 2.5.1 **Nanostructured Solid Oxide Fuel Cells**
- 2.5.2 **Integrated Power Management**
- 2.5.3 **High-efficiency Superconducting Electric Motors**

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NASA/DoD UAPT Interdisciplinary Research Groups

Level 1: UAPT Management

- Dr. Jean-Lou Chameau, Senior Research Officer
  - Dr. Ben Zinn, Director
  - Dr. Dimitri Mavris, Co-Director

Level 2: Research Thrust Areas

- **2.1. Systems Analysis & Tech. Integration** — Lead: Mavris, GT
- **2.2. Enabling Technologies** — Lead: Williams, OSU
- **2.3. Intelligent Engine Systems** — Lead: Zinn, GT
- **2.4. High Performance Components** — Lead: Ahuja, GTRI
- **2.5. Advanced Power Technology** — Lead: Luongo, FAMU

Level 3: Research Tasks

Advanced Design Methods
- 2.1.1 VISSTA Environment
- 2.1.4 High Fidelity Design Tool Development

Adv. Propulsion Materials
- 2.2.4 Nanotechnology
- 2.2.1 Advanced Materials

Advanced Component Technologies
- 2.4.1 Distributed Exhaust Nozzles
- 2.3.4 Active Noise Control
- 2.4.2 Highly Loaded Compressor Blades

Zero Emissions Propulsion
- 2.5.1 Nanostructured Solid Oxide Fuel Cells
- 2.5.2 Integrated Power Management
- 2.5.3 High-efficiency Superconducting Electric Motors

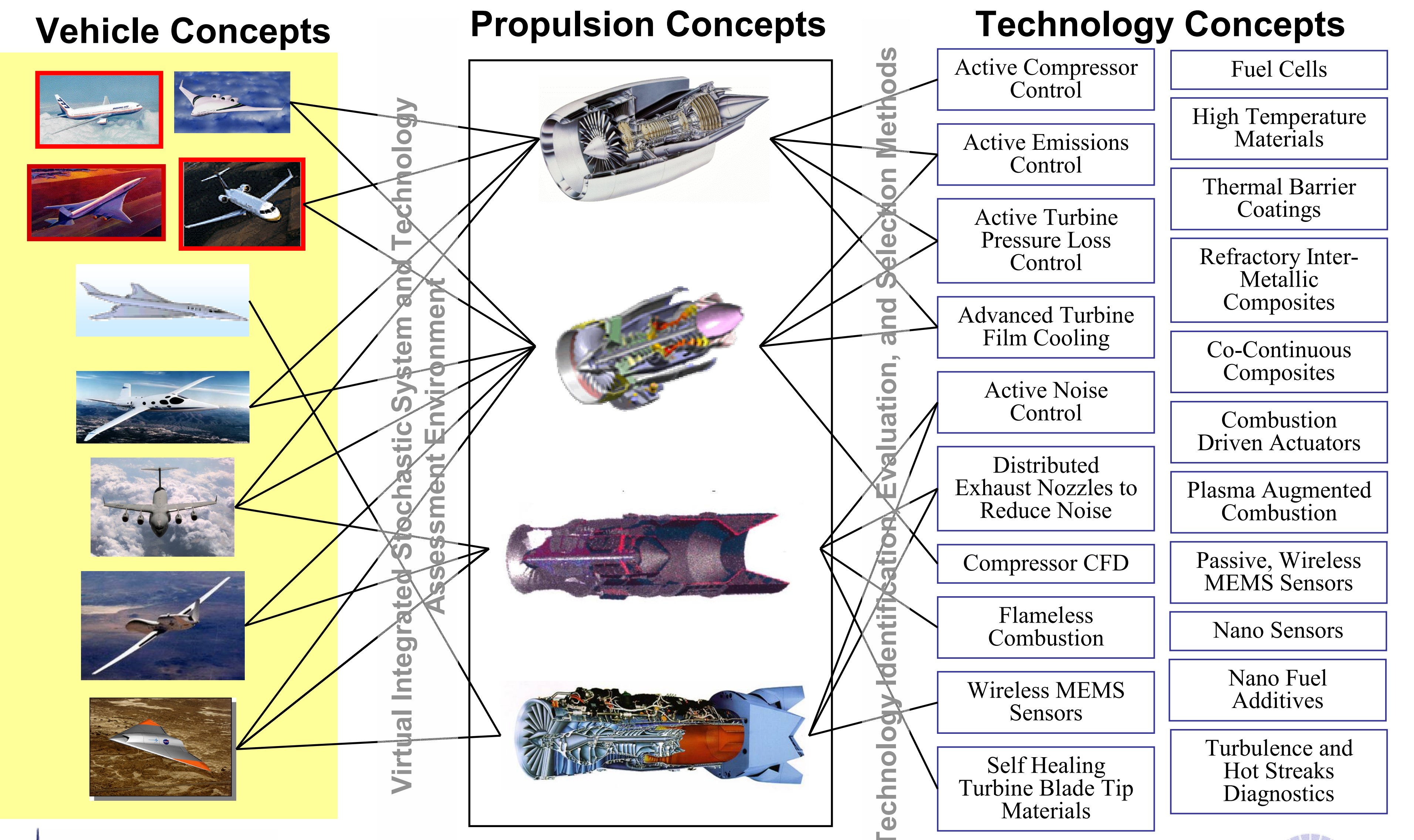
Technology Assessment
- 2.1.2 Analysis Methods for Revolutionary Propulsion Systems
- 2.1.3 UAPT Technology System Assessment

Advanced Controls
- 2.2.2 Actuators
- 2.2.3 Diagnostics and MEMS Sensors
- 2.3.1 Compressor Control
- 2.3.3 Turbine Control

Emissions Reduction Technologies
- 2.3.2 Emissions Control
- 2.4.3 Low Emission, Quiet, Flameless Combustor

Level 3 Research Focused on Key Research Thrust Areas

Virtual System Integration & Evaluation



NASA/DoD UAPT Multidisciplinary Research Strategy

Advancing Science, Engineering, & Technology

LEADS: GIT, OSU, FAMU

Active Compressor Control	Fuel Cells
Active Emissions Control	Nano Fuel Additives
Active Turbine Pressure Loss Control	Thermal Barrier Coatings
Advanced Turbine Film Cooling	Co-Continuous Composites
Active Noise Control	High Temperature Materials
Distributed Exhaust Nozzles to Reduce Noise	Combustion Driven Actuators
Compressor CFD	Plasma Augmented Combustion
Flameless Combustion	Passive, Wireless MEMS Sensors
Wireless MEMS Sensors	Refractory Inter-Metallic Composites
Nano Sensors	Self Healing Turbine Blade Tip Materials
	Turbulence and Hot Streaks Diagnostics

System Level Engineering, Analysis, & Technology Integration

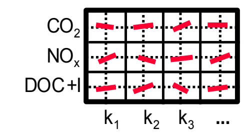
VISSTA

LEAD: GIT-ASDL

Numerical Propulsion System Simulation (NPSS)

Aircraft Synthesis & Sizing: FLight OPtimization System (FLOPS)
Aircraft Life Cycle Cost (ALCCA)

Technology Impact Forecast Environment



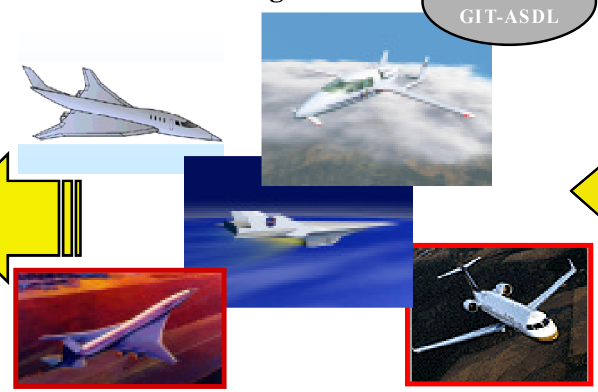
Design Tool Development

- Uncertainty Analysis
- Reliability Based Design
- Design-Oriented CFD
- Life Prediction
- Probabilistic Analysis for Predicting Failure

Fulfill NASA Goals & Objectives

Aircraft Level Integration

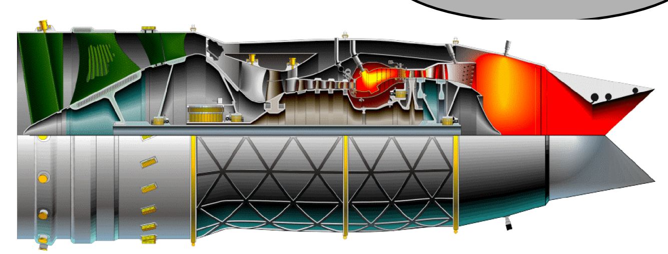
LEAD: GIT-ASDL



Revolutionary and Innovative Aeropropulsion Concepts

Hybrid, Electric, TBCC, Distributed Power, Novel Power Architecture

LEADS: GIT, OSU, FAMU



NASA Goals

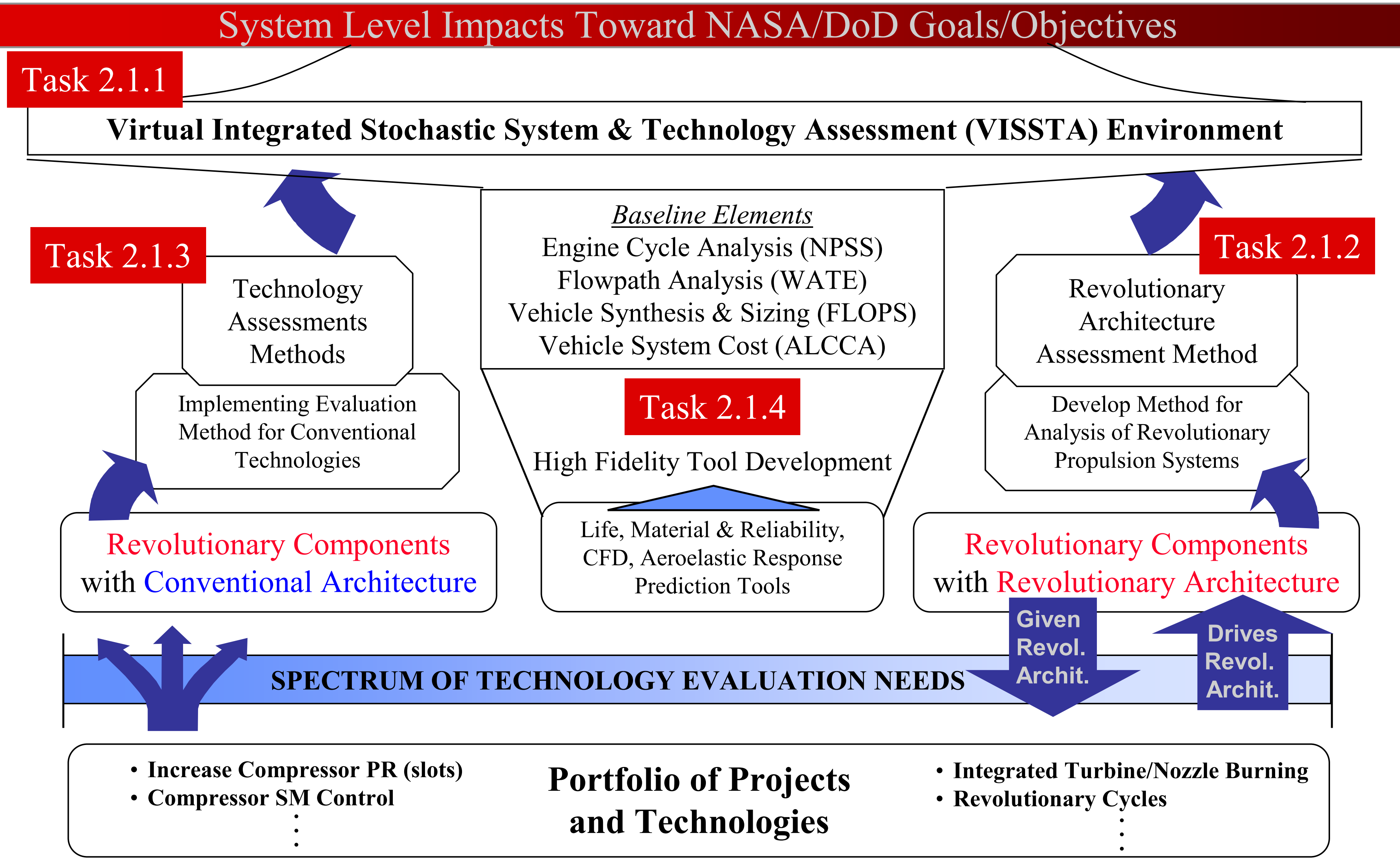
Goal 1: Revolutionize Aviation
Reduce Accident Rate 10X
Reduce Emissions 80%
Reduce Noise 4X
Triple System Capacity
Decrease Door to Door Time 2/3

Goal 2: Advanced Space Transp.
Mission Safety
Mission Affordability
Mission Reach

Goal 3: Pioneer Tech Innov.
Engineering Innovation
Technology Innovation

Goal 4: Commercialized Tech.

Systems Engineering Analysis & Technology Integration Motivation



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2.1: Systems Engineering Analysis & Technology Integration

2.1.1: Formulation, Development & Creation of VISSTA Environment

PI: Dr. Dimitri Mavris, School of AE, ASDL

Science & Technology Objective(s):

- Given a set of technologies, engine architecture, and vehicle concept, determine the overall system impacts and map them against NASA/DoD's overall objectives rapidly and efficiently

Collaborations:

- Government - NASA GRC (Base R&T, ASAO - Bill Haller), LaRC (SAB - Robert McKinley), ONR (Affordability Initiative), NIA (Revolut. Concepts)
- URETI - Practically all UAPT partners
- Synergism with existing programs - NASA UEET Systems Evaluation

Proposed Approach:

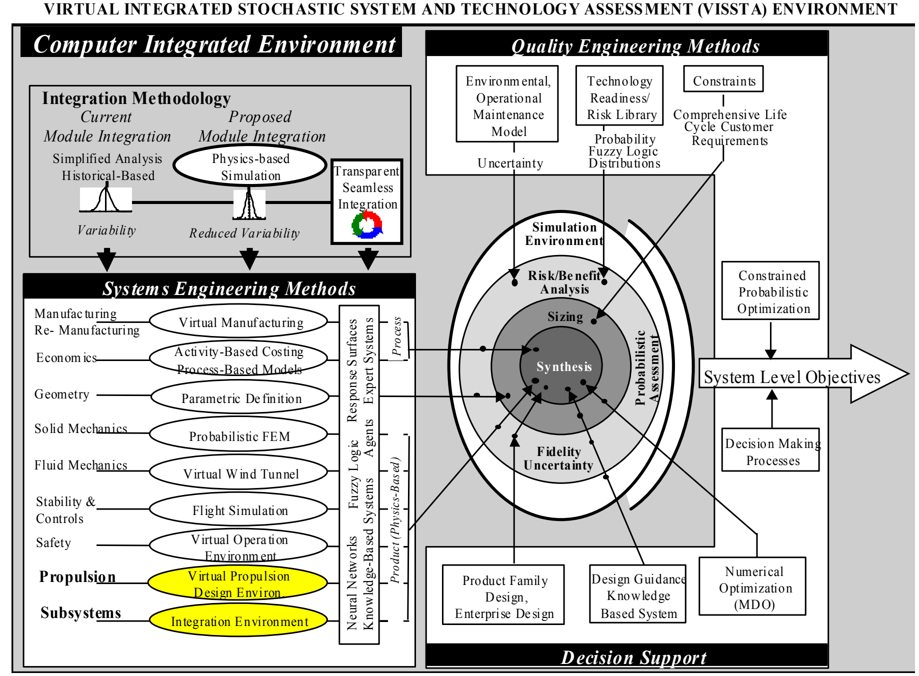
- Formulation, development and creation of a VISSTA environment based on NPSS for propulsion element and LaRC SAB's vehicle system design tools
- Physics-based, integrated, decision making environ.
- Implementation of a method for analysis of propulsion technology concepts
- Based on extensive experience using TIES for conventional technologies
- Accounts for the impact of fidelity, operational, & technological uncertainty

Milestones/Accomplishments:

- Provided on separate slide

Explanatory Figure, Picture, or Graphic:

VIRTUAL INTEGRATED STOCHASTIC SYSTEM AND TECHNOLOGY ASSESSMENT (VISSTA) ENVIRONMENT



NASA Relevance/Impact:

Pioneer Technology Innovation

Enabling a Revolution in Aerospace Systems

- Develop the advanced engineering tools, processes and culture to enable rapid, high-confidence, and cost efficient design of revolutionary systems

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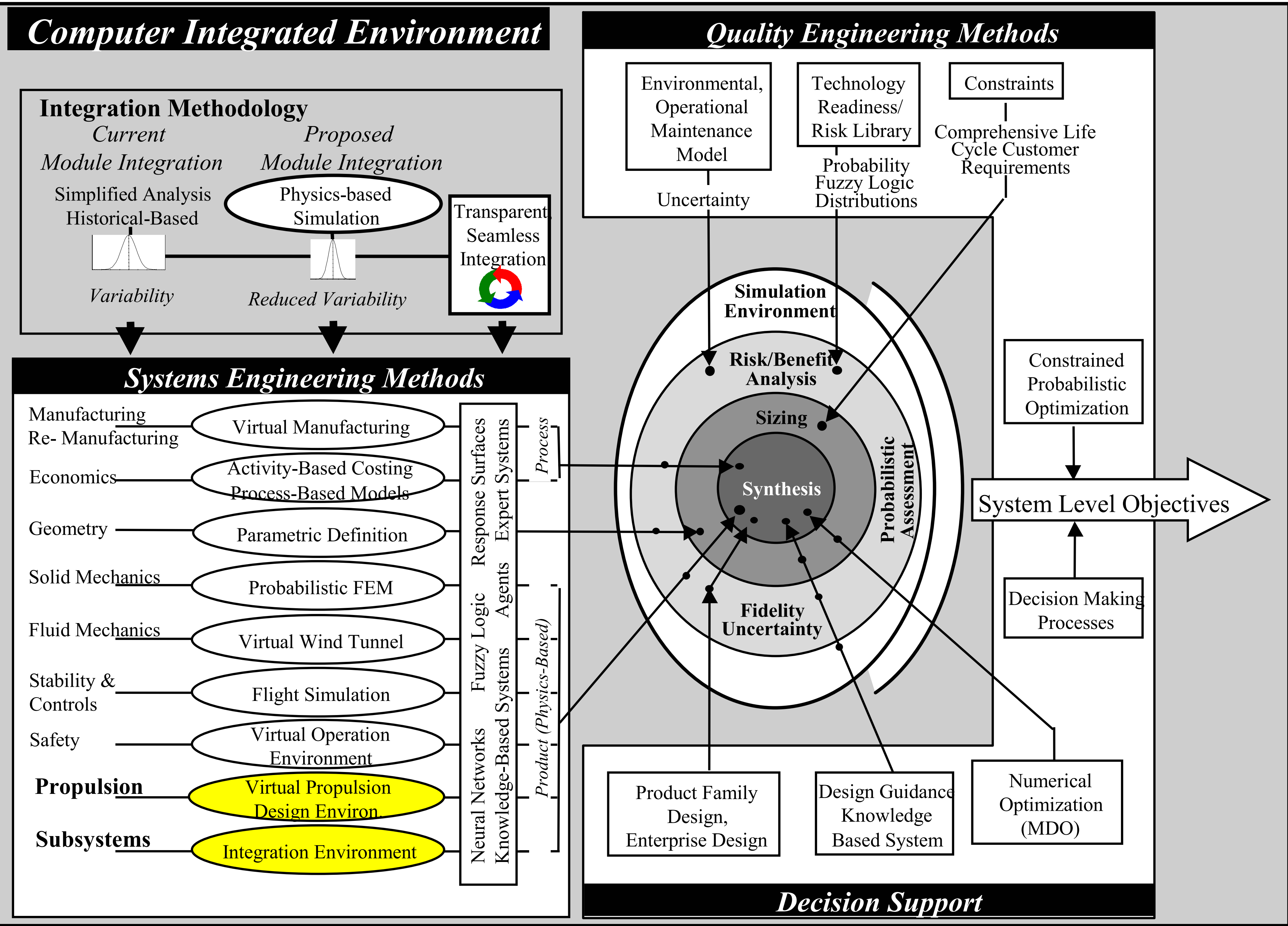
VIRTUAL INTEGRATED STOCHASTIC SYSTEM AND TECHNOLOGY ASSESSMENT (VISSTA) ENVIRONMENT



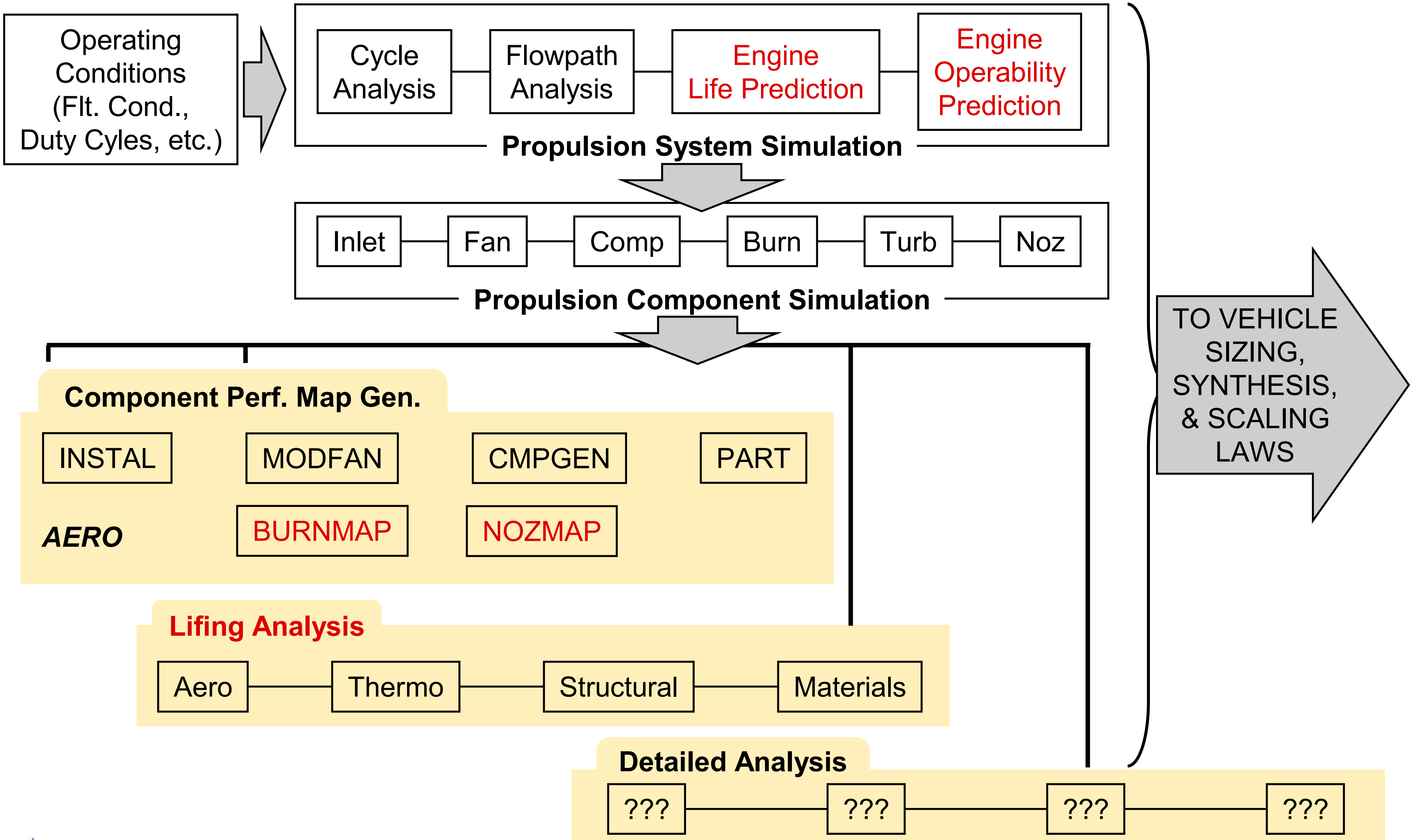
2.1.1: VISSTA Environment Functionality

- Assess technologies in a quantitative manner
  - Facilitate assessment evaluations, guide technology development based on potential benefit to NASA and DoD's overall objectives and/or uncertainty reduction for TRL advancement
- Methodology to handle evolutionary as well as revolutionary concepts and technologies.
- Collection of existing tools utilized at NASA GRC when possible to ensure commonality
- Provide "hooks" to needed simulation tools
- Probabilistic formulation to quantify fidelity, assumptions, operational, and technological uncertainties and to propagate them to the system level so as to support risk based assessments

2.1.1 VISSTA Environment Functionality (cont'd)

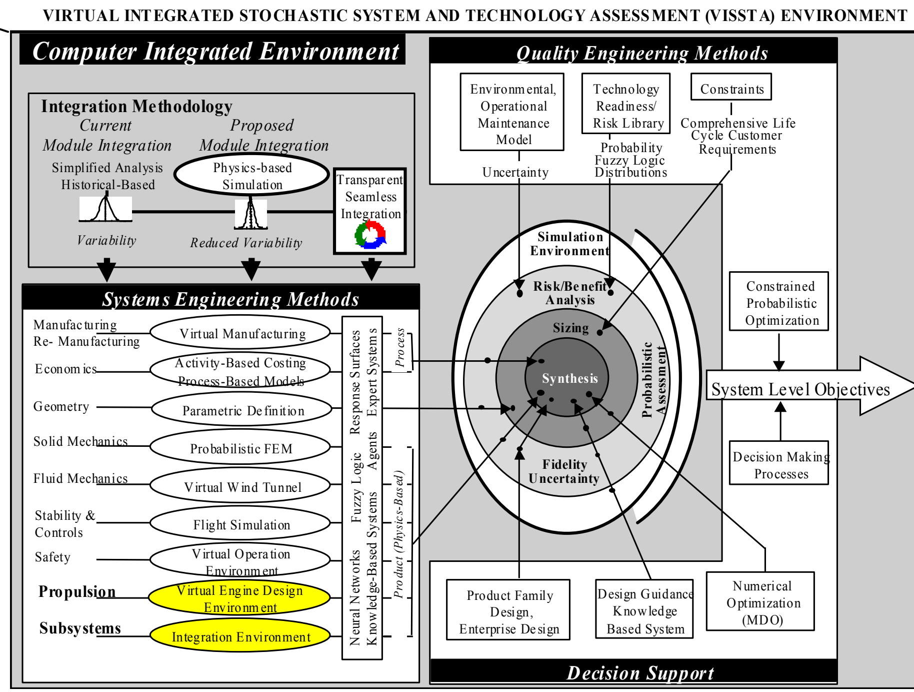
- Emphasis on Virtual Propulsion Design (VPD) environment creation
  - Numerical Propulsion System Simulation (NPSS) based to ensure synergy with GRC/Industry vision of such high fidelity environment
- Leverage vehicle integrated, physics-based, design environment co-sponsored by NASA LaRC's SAB and decision-making, technology assessment methods developed for ONR
- Provide capability to model, integrate, and assess proposed technologies in existing as well as revolutionary propulsion architectures and vehicle concepts

2.1.1 Example of VPD Environment (Turbine Based)



2.1.1 Research Leveraging Compliments & Enhances VISSTA

Virtual Integrated Stochastic System and Technology Assessment (VISSTA) Environment



Leveraging for Task 2.1.2

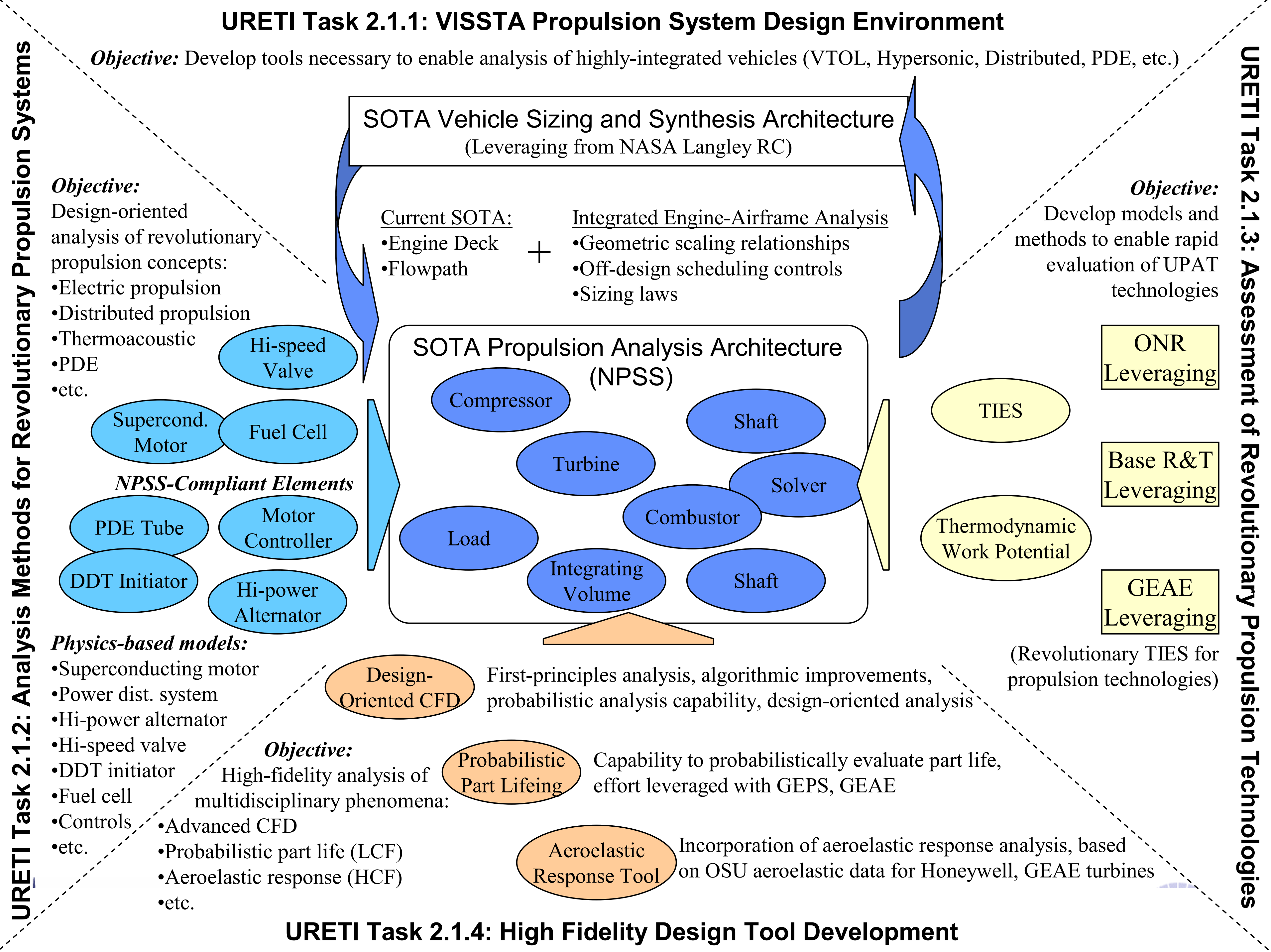
NASA GRC Base R&T Rev-TIES

Leveraging for Task 2.1.1

NASA LaRC Next Generation Synthesis & Sizing Core

Leveraging for Task 2.1.3

ONR TIES Development


URETI Task 2.1.1: VISSTA Propulsion System Design Environment
Objective: Develop tools necessary to enable analysis of highly-integrated vehicles (VTOL, Hypersonic, Distributed, PDE, etc.)
SOTA Vehicle Sizing and Synthesis Architecture
(Leveraging from NASA Langley RC)
Current SOTA:
•Engine Deck
•Flowpath
+
Integrated Engine-Airframe Analysis
•Geometric scaling relationships
•Off-design scheduling controls
•Sizing laws
SOTA Propulsion Analysis Architecture (NPSS)
Compressor
Shaft
Turbine
Solver
Combustor
Load
Integrating Volume
Shaft
URETI Task 2.1.2: Analysis Methods for Revolutionary Propulsion Systems
Objective:
Design-oriented analysis of revolutionary propulsion concepts:
•Electric propulsion
•Distributed propulsion
•Thermoacoustic
•PDE
•etc.
Hi-speed Valve
Supercond. Motor
Fuel Cell
NPSS-Compliant Elements
PDE Tube
Motor Controller
DDT Initiator
Hi-power Alternator
Physics-based models:
•Superconducting motor
•Power dist. system
•Hi-power alternator
•Hi-speed valve
•DDT initiator
•Fuel cell
•Controls
•etc.
URETI Task 2.1.3: Assessment of Revolutionary Propulsion Technologies
Objective:
Develop models and methods to enable rapid evaluation of UPAT technologies
ONR Leveraging
TIES
Base R&T Leveraging
Thermodynamic Work Potential
GEAE Leveraging
(Revolutionary TIES for propulsion technologies)
Design-Oriented CFD
First-principles analysis, algorithmic improvements, probabilistic analysis capability, design-oriented analysis
Objective:
High-fidelity analysis of multidisciplinary phenomena:
•Advanced CFD
•Probabilistic part life (LCF)
•Aeroelastic response (HCF)
•etc.
Probabilistic Part Lifeing
Capability to probabilistically evaluate part life, effort leveraged with GEPS, GEAE
Aeroelastic Response Tool
Incorporation of aeroelastic response analysis, based on OSU aeroelastic data for Honeywell, GEAE turbines
URETI Task 2.1.4: High Fidelity Design Tool Development

2.1.1 Tentative 1st Year Work Plan

	TASKS	8/02	9/02	10/02	11/02	12/02	1/03	2/03	3/03	4/03	5/03	6/03	7/03	8/03
		2.1.1 Virtual Integrated Stochastic System & Technology Assessment Environment												
1	Develop work plan	■	■	■										
2	Formulate VISSTA architecture (define major modules)				■	■	■	■	■	■	■	■	■	■
3	Formulate Virtual Propulsion Design environ. (NPSS based formulation)				■	■	■	■	■	■	■	■	■	■
4	Define major VPD components (NPSS based)							■	■					
5	Define example problem for VPD to tackle				■	■								
6	Formulate method to analyze example problem						■	■	■					
7	Begin collection/development of tools to populate VPD							■	■	■	■	■	■	■
	Milestones:													
	Present initial work plan to NASA & DoD			▲										
	Progress on VISSTA Module Identification												▲	
	Progress on VPD Component Identification												▲	
	Example Problem Definition								▲					

2.1 Systems Engineering Analysis & Technology Integration

2.1.2 Analysis Methods for Revolutionary Propulsion Systems

PI: Dr. Dimitri Mavris, School of AE, ASDL

Science & Technology Objective(s):

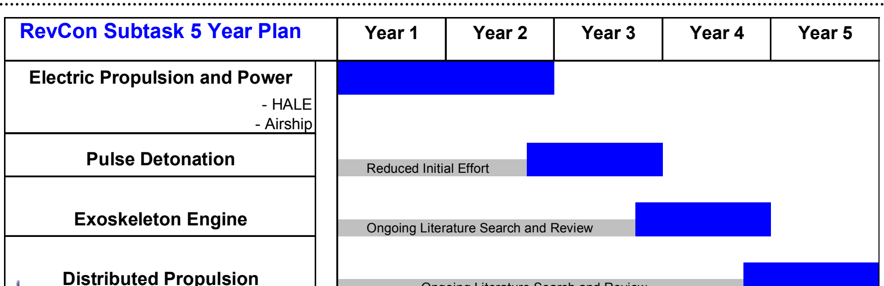
- To develop methods to assess revolutionary propulsion systems (e.g. exoskeleton engine, pulse detonation engine, electric propulsion & power, distributed propulsion)

Collaborations:

- Government - NASA GRC (ASAO - Base R&T)
- URETI - GTRI (Parekh), FAMU (Luongo)
- Industry - Gulfstream (Woltz)

Proposed Approach:

- Vehicle/Concept Configuration
- Vehicle Modeling
- Power Requirements Definition
- Propulsion & Power Simulation
- Subsystem Simulation
- Component Simulation



NASA Relevance/Impact:
Pioneer Technology Innovation

Enabling a Revolution in Aerospace Systems

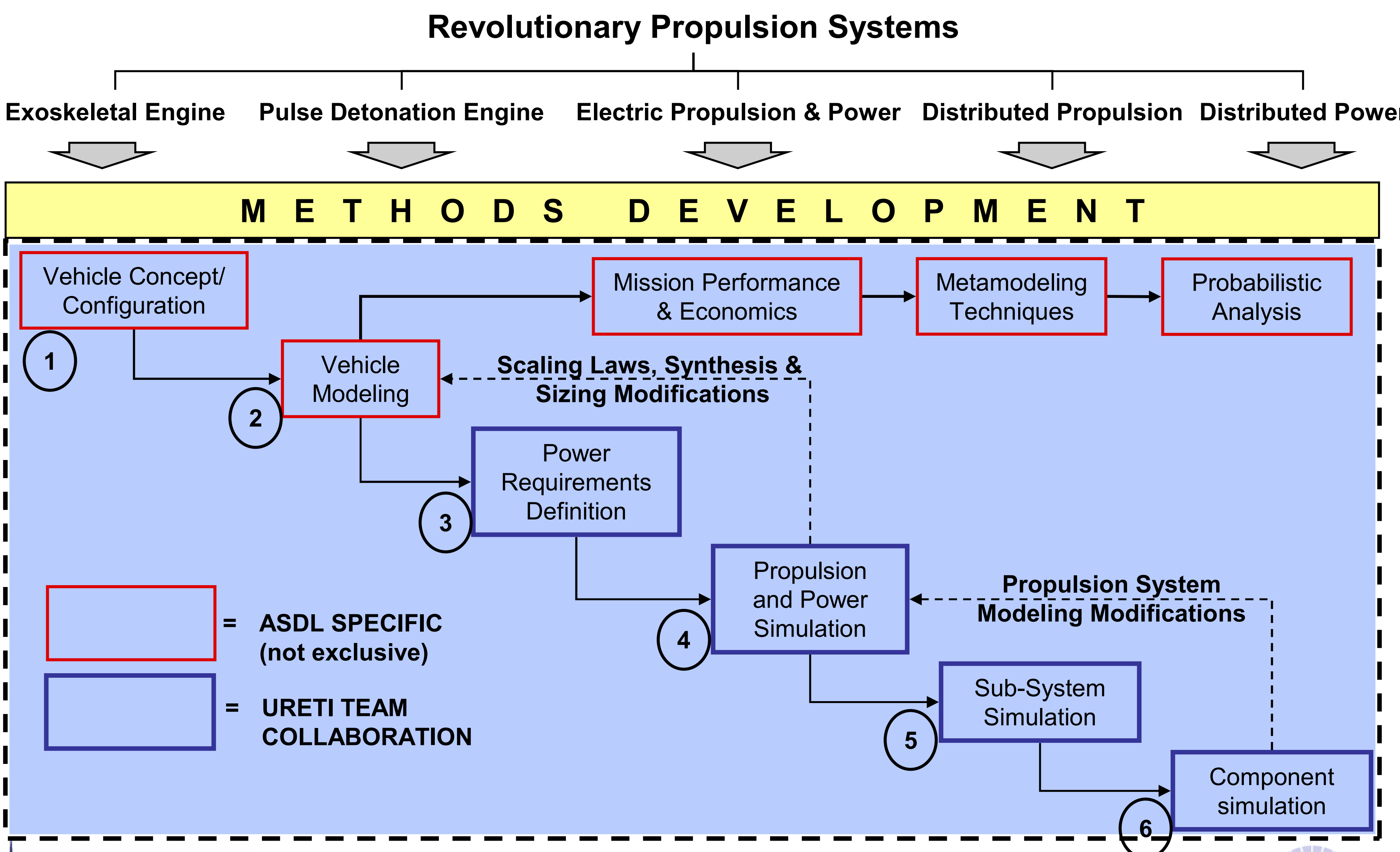
Engineering Innovation - Develop advanced engineering tools, processes and culture to enable rapid, high-confidence, and cost efficient design of revolutionary systems.

Technology Innovation - Develop the revolutionary technologies and technology solutions to enable fundamentally new aerospace system capabilities or new aerospace missions

Milestones/Accomplishments:

- Develop understanding of relevant issues
- Identify potential revolutionary technologies
- Develop appropriate evaluation metrics
- Identify necessary tools and codes for analysis and simulation
- Develop aircraft models
- Perform technology assessments

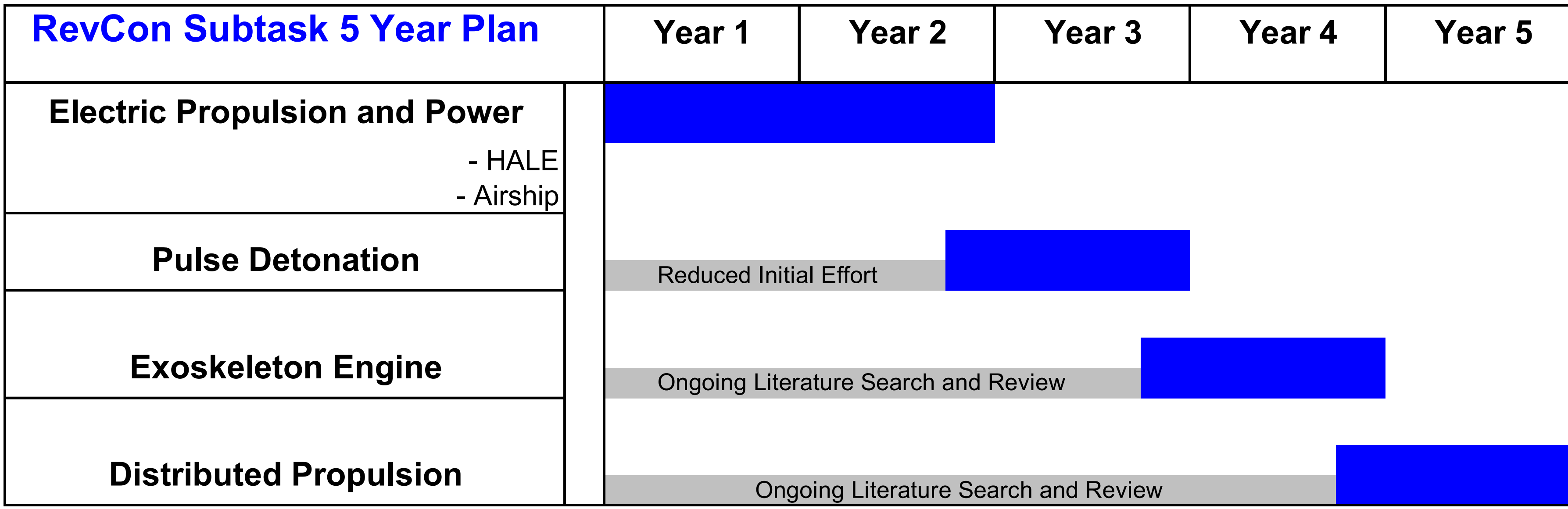
2.1.2 Proposed Approach



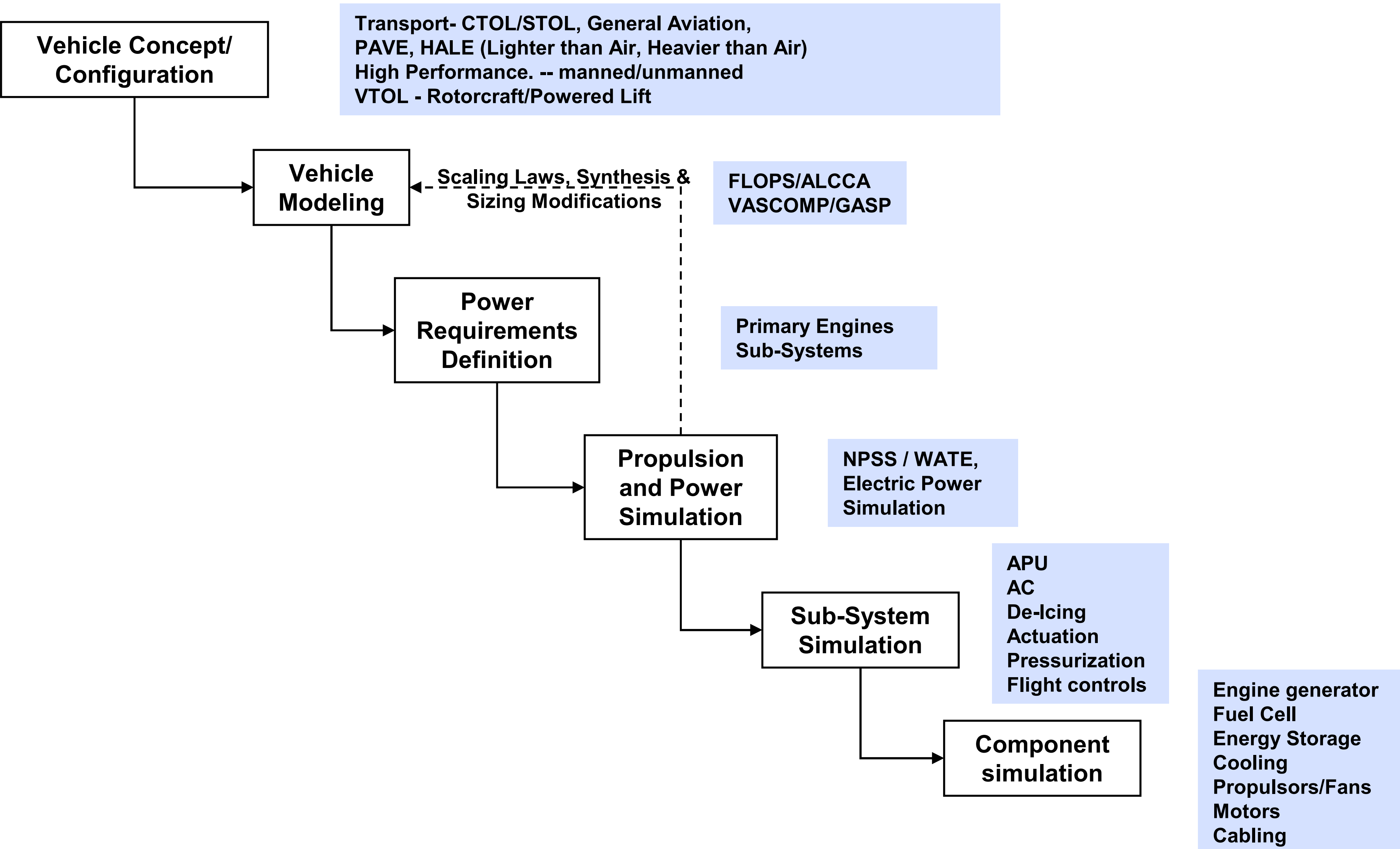
2.1.2 Challenges

PERCEIVED CHALLENGES				
	Exoskeletal Engine	***Pulse Detonation Engine***	***Electric Airplane***	***Distributed Propulsion***
1	•••	Configuration Impacts	Configuration Impacts	Configuration Impacts
2	Engine/Vehicle Integration	Engine/Vehicle Integration		Control System Internal Configuration
3	•••	•••		
4	Flowpath Analysis	Flowpath Analysis	Power System Simulation	Distributed Propulsion vs. Power Unit
5	Accessories (starter, gen,etc.)	Accessories (starter, gen,etc.)	Power Distribution	Micro Engine Performance Est.
6	Casing Design	Unsteady Combustion Process	Fuel Cell, Motor/Gen. Cooling	Component Performance Est.
Advantages	Fatigue Alleviation	Mechanical Simplicity	Environmental Benefits	Redundancy
Collaborators	GRC (ASAO)	GRC (ASAO)	FAMU, GTRI, LaRC (SAB), GRC (ASAO)	LaRC (SAB), GRC (ASAO)

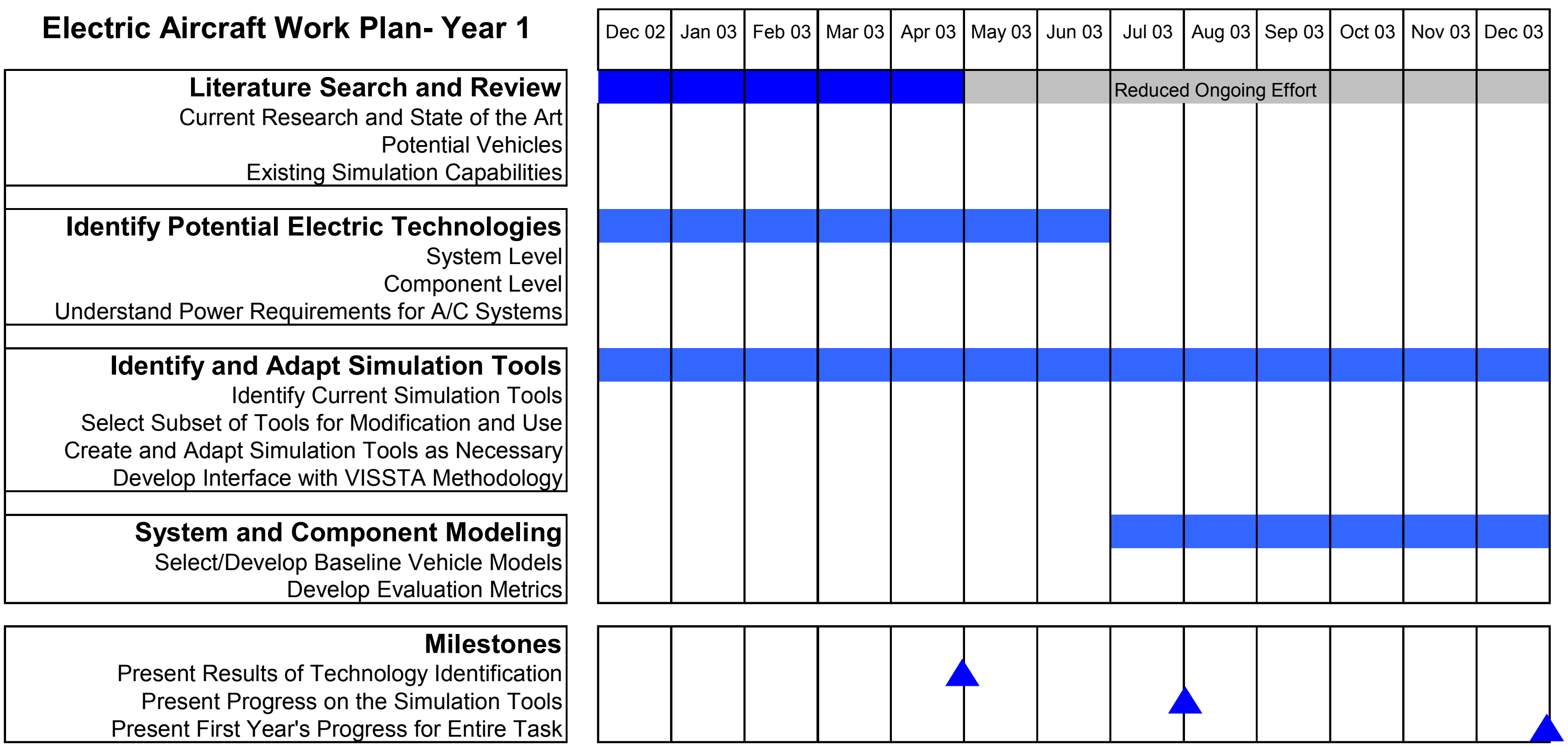
2.1.2 Five-Year Tentative Plan



2.1.2 Example: Electric Propulsion & Power



2.1.2 Example: Tentative First Year Work Plan



2.1 Systems Engineering Analysis & Technology Integration

2.1.3 Assessment of Proposed Revolutionary Technology

PI: Dr. Dimitri Mavris, School of AE, ASDL

Science & Technology Objective(s):

- Develop system-level models for UAPT technologies
- Evaluate UAPT proposed technologies against NASA aerospace enterprise goals

Collaborations:

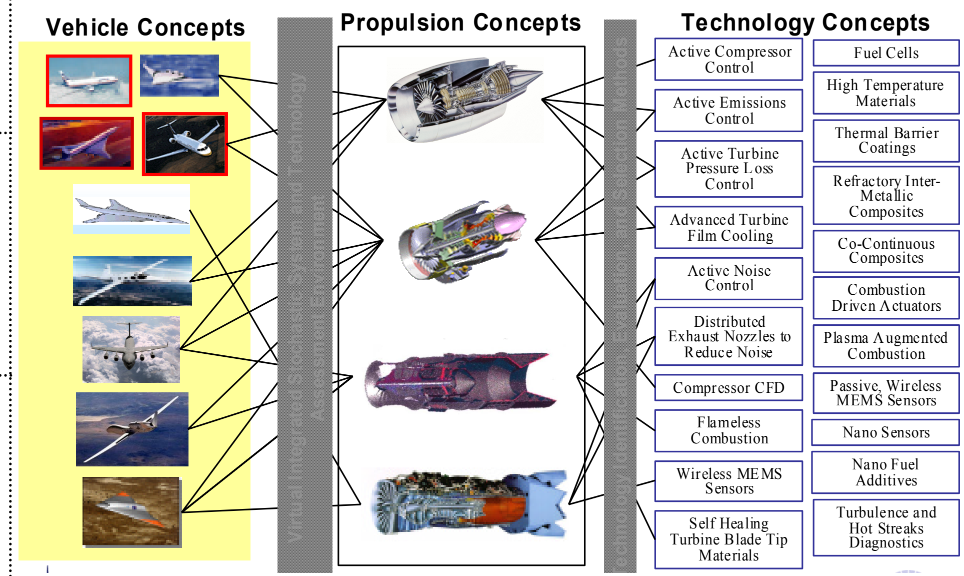
- Government - NASA GRC (S&T Base, ASAO)
- URETI - All GT URETI partners
- Synergism with existing programs - NASA UEET Systems Evaluation

Proposed Approach:

- Work with various URETI team members to develop system-level representations for each technology
- Implement a method to estimate system impact of UAPT propulsion technology concepts
- Work with URETI members to track technology benefit and TRL through the project life
- Integrate and/or utilize elements of VISSTA where appropriate

Milestones/Accomplishments:

- Establish initial models for each UAPT technology
- Monthly or quarterly technology "tracking meetings"
- Annual evaluation of technology status and TRL



NASA Relevance/Impact:

- Provide framework to assist NASA/DoD in evaluating impact of UAPT technologies
- Provide tracking function relating current technology status to vehicle-level impact

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2.1.3 Assessment of Proposed Revolutionary Technology

- ***Objective:*** Develop models for the various UAPT technologies that can be used by NASA/DoD to determine the overall system impact rapidly and efficiently
- ***Motivation:***
  - It is of prime importance that UAPT technologies be "value added" towards the achievement of those goals (no stove-pipe technologies)
  - Must have a *systematic*, *organized* means of tracking and evaluating the progress of various UAPT technologies with respect to NASA goals
- ***Background:***
  - Based on extensive experience using TIES for conventional technologies
  - Will ultimately utilize many elements of VISSTA and associated high-fidelity analyses integrated therein
  - Stochastic formulation accounts for the impact of uncertainty in subsystem performance

2.1.3 Assessment of Proposed Revolutionary Technology

NASA Goals

Technology Gap ???

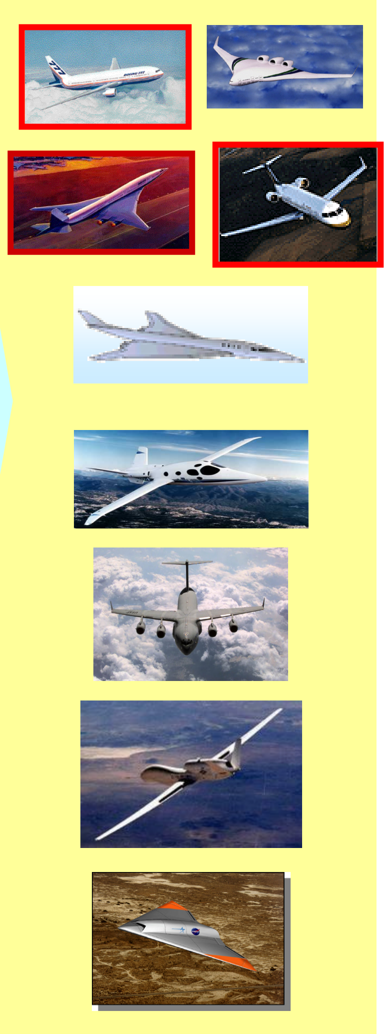
NASA Goals	10/15 Year Goal	25 Year Goal
Goal 1: Revolutionize Aviation:		
Objective 1: Increase Safety (Accident Rate)	Reduce 5X	10X
Objective 2: Reduce Emissions (NOX, CO2)	Red. 70%,25%	80%, 50%
Objective 3: Reduce Noise	Reduce 2X	4X
Objective 4: Increase Capacity	Double	Triple
Objective 5: Increase Mobility (Door to Door)	1/2	2/3
Goal 2: Advance Space Transportation		
Objective 6: Mission Safety	Reduce 40X	100X
Objective 7: Mission Affordability	Reduce 10X (LEO)	10X (IOT)
Objective 8: Mission Reach	Reduce 2X	10X
Goal 3: Pioneer Technology Innovation		
Objective 9: Engineering Innovation	Rapid, Advanced, $ Effective	
Objective 10: Technology Innovation	Rev. Tech's and Solutions	
Goal 4: Commercialize Technology		

URETI

UEET, QAT
TBCC, ISAT, etc.

System-Level Technology Impact

Vehicle Concepts



Revolutionary Technologies

Technology 1: ??????
Technology 2: ???????
Technology 3: ???????
…..

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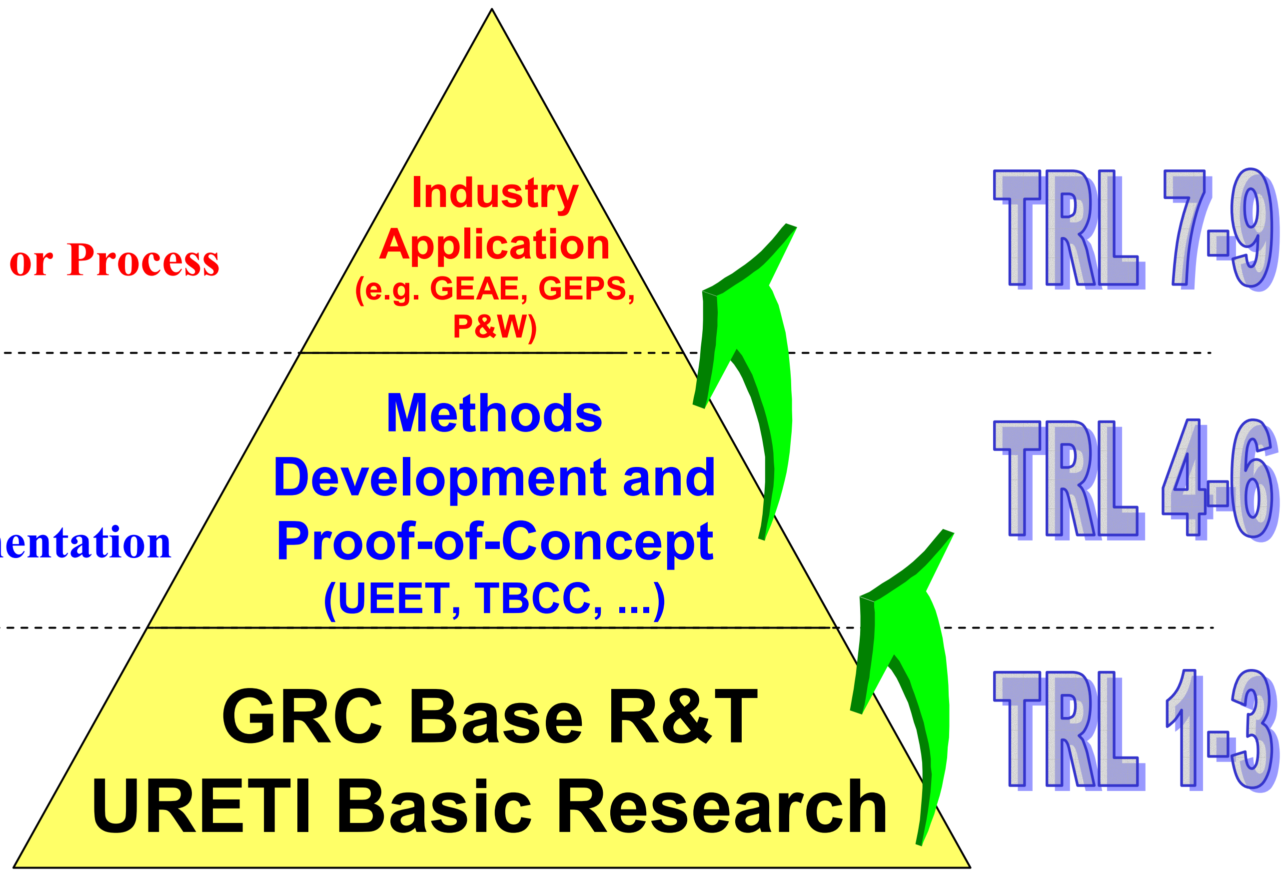
2.1.3 Assessment of Proposed Revolutionary Technology

UAPT technologies are tracked through their program life and are transitioned at TRL 4

- Full System Prototype
- Applied to Actual System or Process

- Application Formulation
- Verification
- Proof-of-Concept Implementation

- Basic Principles
- Analytical Formulation
- Initial Testing



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2.1.4 High Fidelity Design Tool Development

2.1.4.1 Design-Oriented CFD

PI: Prof. Sankar (GT Aerospace); Collaborators: Dunn (OSU), Mavris, Menon (GT Aerospace)

Motivation

- Substantial progress has been made in first-principles based modeling of turbomachinery components.
- There is a need for incorporating these methods in design environments, taking into account probabilistic variations in engine operation conditions and parameters.
- Prior to use in design, these analyses must be validated for existing configurations, particularly for unsteady flow conditions.

Approach & Collaborators (Sankar, Dunn, Mavris, Menon)

- Starting point is unsteady CFD solvers that have been developed at NASA Glenn, and at universities (Ga Tech, MSU).
- These methods will be enhanced with algorithms that have Improved spatial and temporal accuracy, and improved temporal stability. First principles based turbulence modeling using a combination of RANS and LES techniques will be used.
- These analyses will be carefully validated against NASA Glenn/OSU experiments.
- The analyses will, in parallel, be incorporated into Ga Tech design methodologies.

Relevance

- The CFD tools developed and validated in this task will aid in the assessment of proposed technologies against the NASA Aerospace Enterprise stated goals.
- These tools will quantify uncertainty via stochastic analysis, and employ physics-based modeling to track progress of technologies as applied to each category of NASA's Aerospace Enterprise baseline vehicles.

Year 1 Schedule/Resource

- Lead: Sankar, Dunn, Mavris, Menon
- Support/Collaborators: NASA, GE Partners
- No. of Students: 2
- **Tasks:**
  - Acquisition of NASA CFD analyses as appropriate.
  - Incorporation of high order algorithms into CFD methods.
  - Selection of cases for validation
  - Preliminary calibration of the analysis tools.
  - Developments of data exchange formats between analysis and design.

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2.1.4.1 Background

- Over the past several years, a number of first-principles based analyses have been developed for modeling turbo-machinery components.
- Algorithmic improvements (improved spatial accuracy, enhanced stability and robustness, and solution efficiency) are still needed.
- Before these are used in a design environment, they should be carefully validated against unsteady and steady experimental data, incorporating aeroelastic effects where needed.
- Finally, ‘hooks’ must be developed for exchanging data between these methods and first-principles based design methods.

2.1.4.1 Tentative First Year Tasks

- Examine existing first-principles based methods; select two or three methods for further study.
- Implement high order upwind schemes (up to 7th order), first principles based turbulence mdoels (LES schemes by Menon), and implicit time marching algorithms with enhanced stability.
- Select a set of cases for code calibration (Dunn, OSU).
- Examine what data is needed for the design tools under development, and begin developing means for seamless exchange of data between the CFD methods and the design tools, using modern software engineering tools.

2.1.4 High Fidelity Design Tool Development
2.1.4.2 Probabilistic Part Life Methods/Material Requirements Definition

PI: Dr. Dimitri Mavris (GT ASDL), Dr. Jim Williams (OSU)

Science & Technology Objective(s):

- Develop methods to facilitate evaluation of materials design impact on part life and system performance
- Develop a "direct analysis" to allow the prediction of part life
- Develop an "inverse analysis" to allow the estimation of material properties required to meet design goals

Collaborations:

- Government - NASA GRC (A. Misra), ASAO (Haller)
- URETI - OSU (Dunn)
- Industry - GEAE, GEPS
- Synergism with existing NASA programs
  UEET, High Op. Temp. Project, Ultra Safe Prop. Project
- Interface with Air Force Research Lab.

Proposed Approach:

- *System Design for Direct Analysis:*

– Modeling of the complete turbine engine with details of the hot section flow path

- *Part Design for Direct Analysis:*

– Geometry definition, BC's, FEA, & failure modes to probabilistically determine Part Life using meta-modeling

– Application of Monte Carlo and/or Fast Probability Integration techniques to quantify and reduce uncertainty

- *Materials Research:*

– Material & Life Limiting Properties; Micro Material Configuration; Processing Methods

– Use initial results as a basis for developing an "*Inverse Analysis"* to materials design/selection

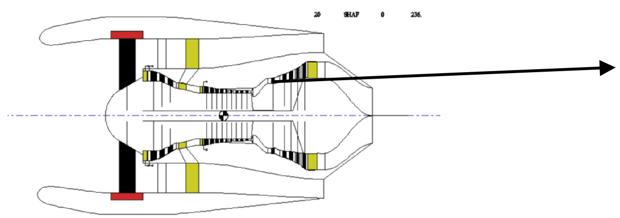
NASA Relevance/Impact:

Engineering Innovation

- Develop the advanced engineering tools, processes and culture to enable rapid, high-confidence, and cost efficient use of high temperature materials in advanced turbine engines.

Technology Innovation

- Develop the technology solutions that enable the definition of new materials for advanced aerospace systems

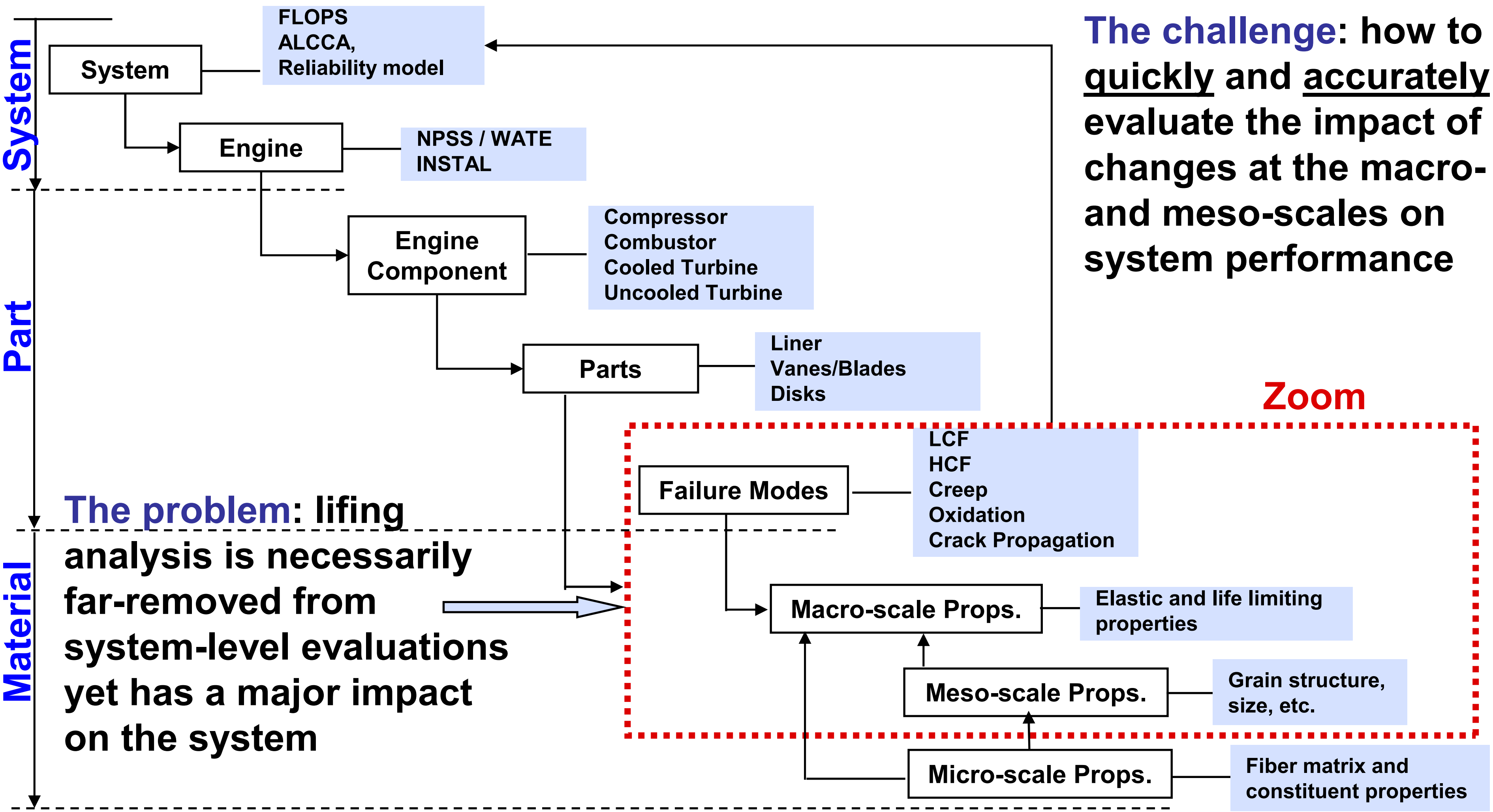


Milestones/Accomplishments:

- Review and Evaluation of current state of the art and on-going research
- Life prediction of a critical component baseline using an integrated set of tools
- Statistical parameterization of material properties
- Providing set of requirements for new materials as functions of firing temperature and cooling flow rate (driving materials design based on system needs)

2.1.4.2 Lifing/Reliability: The Fundamental Challenge

The challenge: how to **quickly** and **accurately** evaluate the impact of changes at the macro- and meso-scales on system performance



The problem: lifing analysis is necessarily far-removed from system-level evaluations yet has a major impact on the system

2.1.4.2 Proposed Approach for Lifing – Direct Problem

Phase 1: Direct Problem:
Establish System-Oriented Part Lifing Methodology

Given

1. A baseline with a given firing temperature, cooling effectiveness parameter and cooling flow fraction

Source

Tools/Data Required

2. Internal & external boundary conditions (temperature, pressure, heat transfer coefficients) *(GT In collaboration w/OSU)*
3. FEA geometric model of the life critical part *(GT/OSU/Industry)*
4. Elastic properties *(OSU)*
5. FEA thermal & structural analysis *(GT)*
6. Life limiting properties *(OSU)*
7. Model of critical failure modes (creep, oxidation, fatigue, crack prop.) *(OSU)*

Output

8. Critical part life, cost, etc. *(GT)*

2.1.4.2 Proposed Approach for Lifing – Inverse Problem

Phase 2: Inverse problem:
Define advanced material requirements

Given Requirements

1. **Specified part life**
2. **Vary firing temperature w/ constant cooling flow fraction** ***OR***
3. **Reduce cooling flow fraction w/ constant firing temperature**
   (**Increased effectiveness and/or increased allowable metal temperature is necessary**)

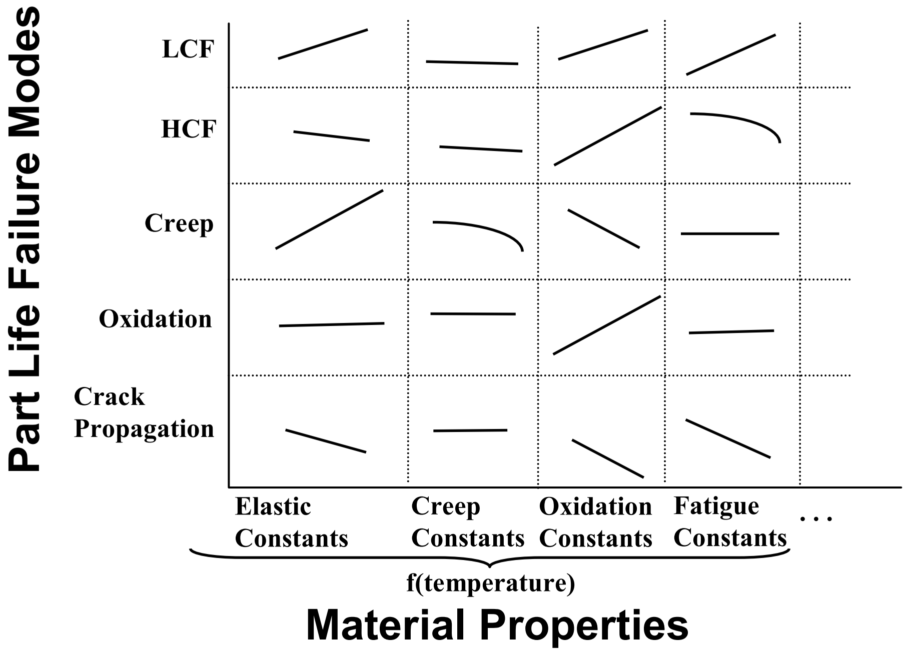
Tools/Data Required

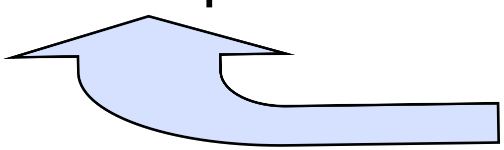
4. **Internal & External boundary conditions (temp, press, heat trans coefficients)**
5. **Statistical parameterization of material properties** ***(GT)***
6. **FEA geometric model of the life critical part** ***(Industry, or Gv't)***
7. **Model of critical failure modes (creep, oxidation, fatigue, crack prop.)** ***(GT)***
8. **Probabilistic meta-model (developed from previous analyses)**

Output

9. **Set of combinations of required elastic and life limiting material properties** ***(GT)***

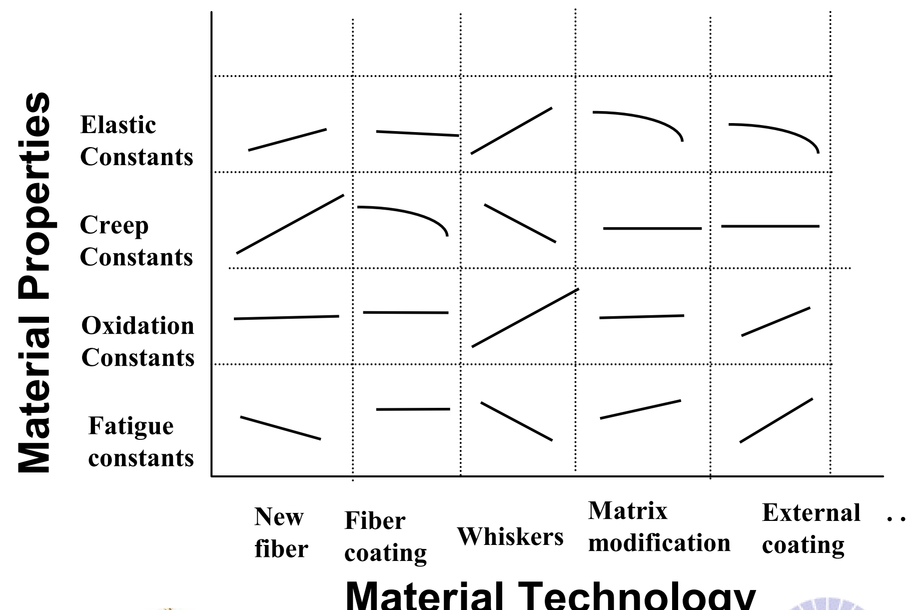
2.1.4.2 Example: Assessment of Low TRL Materials Technology





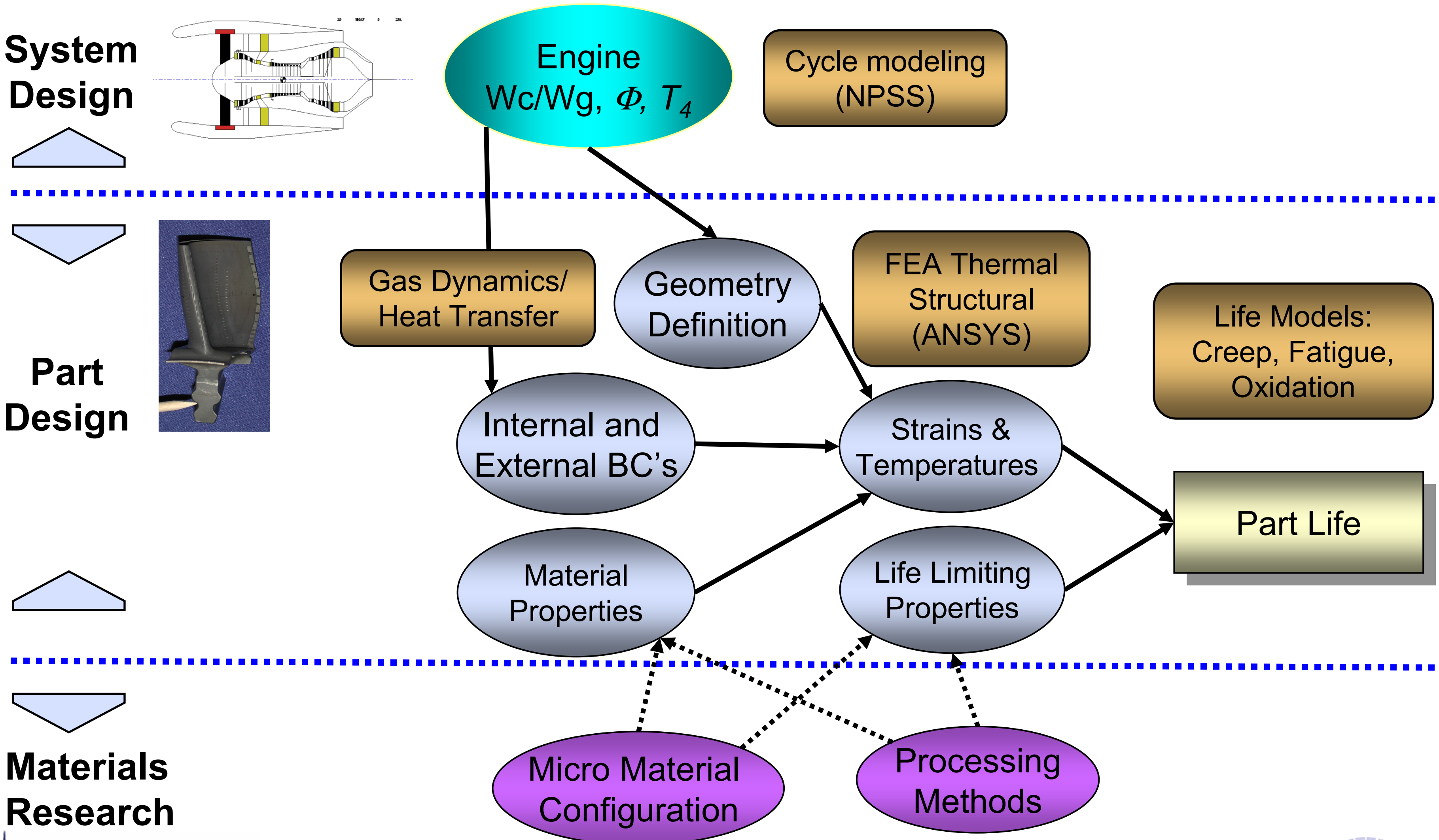
Meta-model representations capture pertinent technology metrics at each level

The solution: *a TIES-like approach theoretically would allow quick and accurate evaluation of materials impact on system-level performance and vice-versa*



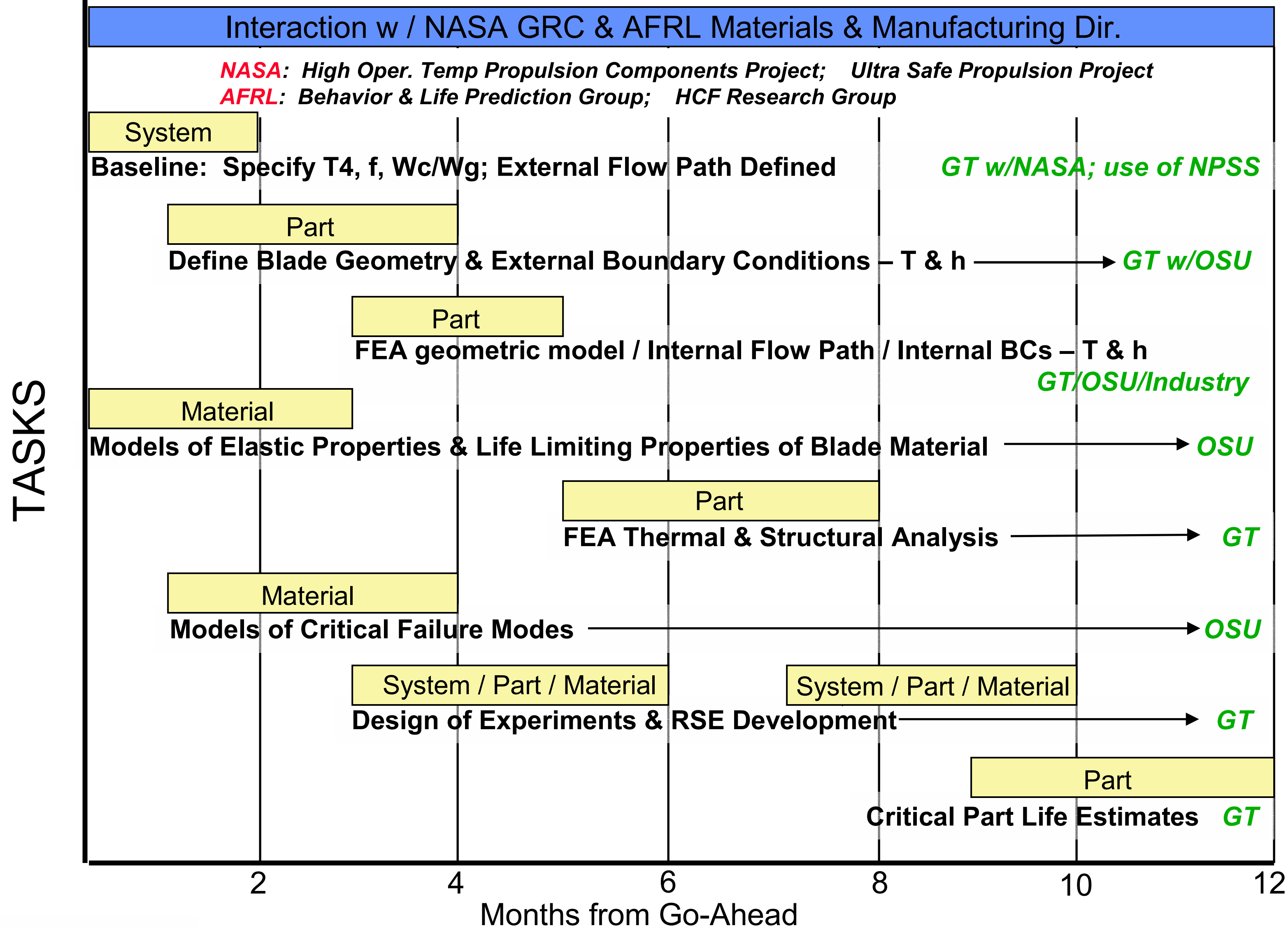
2.1.4.2 Proposed Approach: *Requirements for Materials*

Critical Part: HGP Turbine Bucket – *Step 1 Procedure for the Direct Problem*



2.1.4.2 Tentative First Year Work Plan

Year 1 – Direct Problem to Compute Part Life



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2.1.4 High Fidelity Design Tool Development

2.1.4.3 Aeroelastic Response Prediction Tool Development

PI: Prof. Dunn, Ohio State University; Collaborator: Mavris, GT Aerospace

Science & Technology Objectives:

- Provide relevant experimental results for aeroelastic response for two very different engines.
- Work with GT (Mavris) to integrate experimental results into a practical design system code.

Collaborations:

- Government - NASA GRC and USAF AFRL
- URETI - OSU and Georgia Tech
- Industry - Honeywell, Rolls Royce America, P&W
- Synergism with existing programs - Previous Guide program/NASA and Air Force Program/Air Force

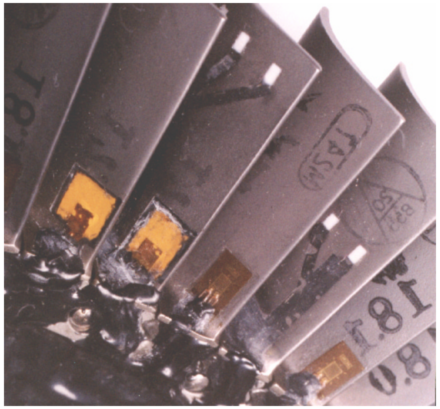
Proposed Approach:

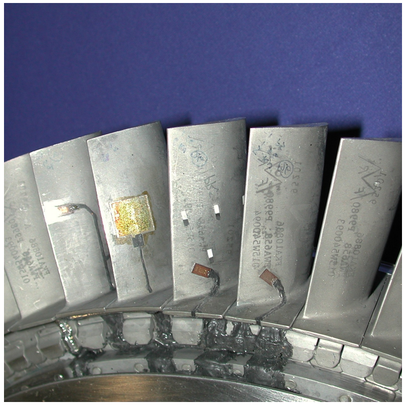
- Integrate existing TFE 731-2 results
- Obtain additional TFE 731-2 results from existing data base
- Perform measurement program for modern vaneless counter-rotating turbine stage.

NASA & Air Force Relevance/Impact:

- TFE 731-2 data set is unique. Impact is on aeroelastic modeling and CFD code development.
- Experimental results for modern VCC stage significantly expands modeling & code capability.

TFE 731-2 blade (l) & Modern blade (r)





Milestones/Accomplishments:

- Transfer existing TFE 731-2 results to Georgia Tech. and incorporate results into structural model for forced response. Industry and NASA are currently comparing initial results with models and CFD codes.
- Mine additional information from TFE 731-2 data set and incorporate results into structural model by working with Georgia Tech, industry, NASA, and Air Force.
- Perform measurement program for modern VCC engine stage. Work with industry and government to determine validity of existing models and CFD codes.

2.1.4.3 Proposed Approach

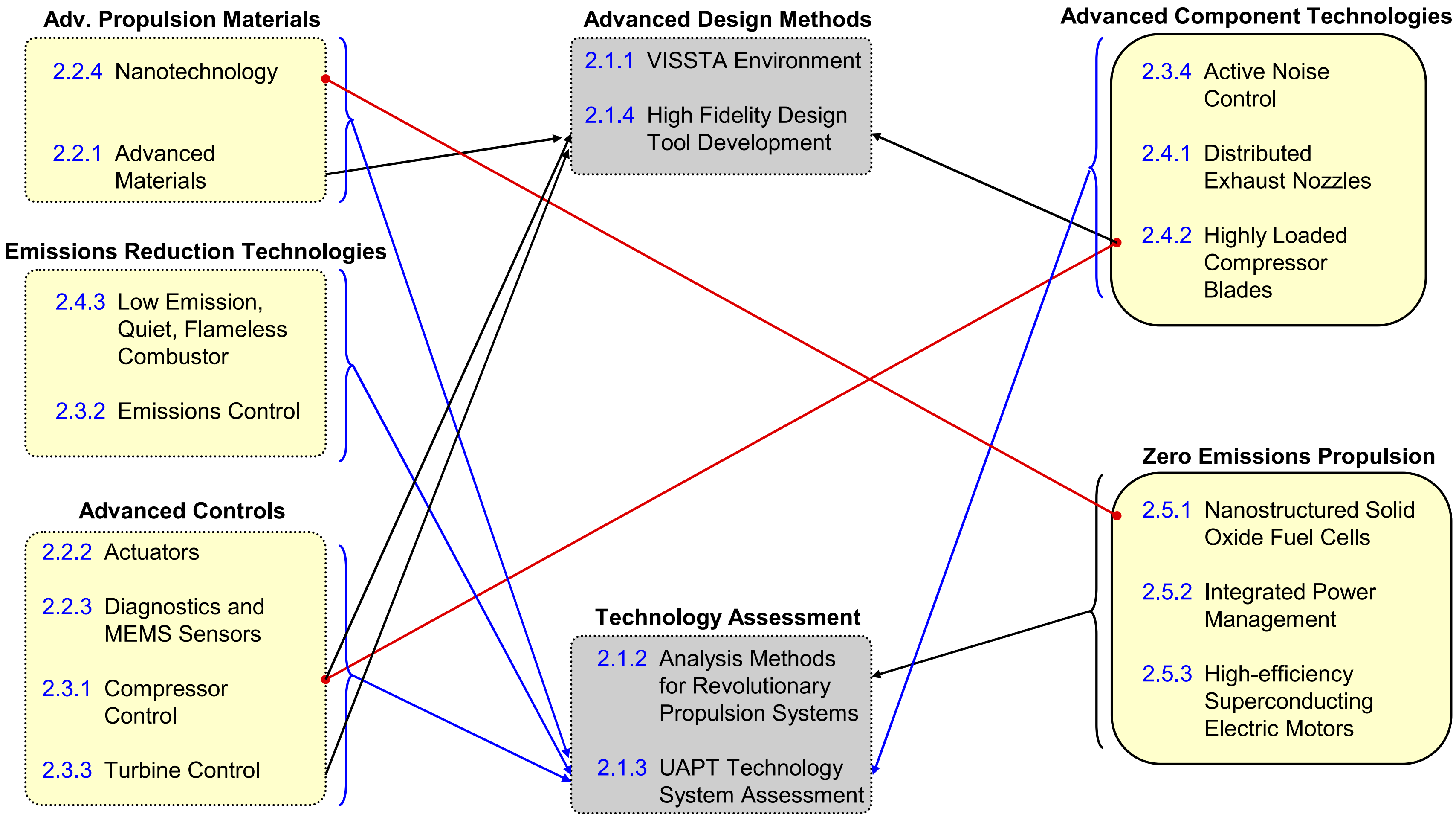
- Modern turbine designs are characterized by large stage pressure ratios and highly loaded airfoils which are susceptible to aeroelastic excitation. High-cycle-fatigue (HCF), which is poorly understood, has become a source of concern for these designs.
- State-of-the-art in experimental techniques have progressed to the point where useful experimental information regarding HCF can now be affordably obtained with sufficient accuracy to interest the design community
- Honeywell TFE 731-2 data is currently available as well as some modeling and CFD (NASA & industry)
  - Older machine that encountered unexpected HCF difficulties
  - Additional significant information can be mined from data set
- Modern vaneless counter-rotating turbine instrumented and ready to be run
  - U.S. Air Force and Industry

2.1.4.3 Tentative First Year Tasks

- Establish official project relationship with collaborators and stake-holders
  - NASA
  - Industry
- Mine existing data set (TFE 731-2) for additional aeroelastic data (near-term, low hanging fruit)
- Begin development of aeroelastic tool incorporating existing data
  - Start with existing models
  - TurboAE aeroelastic analysis
- Prepare for experimental test of modern counter-rotating turbine hardware

Support Slides

UAPT Interdisciplinary Research Links



Research Program Is Highly Interdisciplinary and Cross-Cutting