FAA CLEEN Consortium

Public Plenary Session

GE Aviation
May 4, 2016

Federal Aviation Administration

GE Aviation CLEEN II Topics

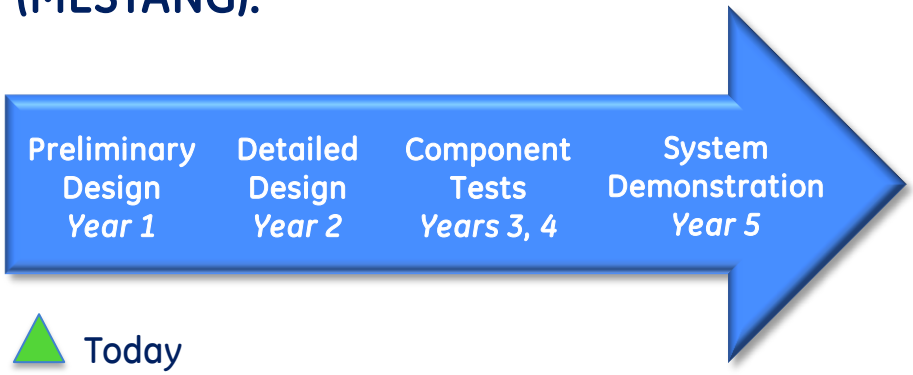
- MESTANG - **M**ore **E**lectric **S**ystems and **T**echnology for **A**ircraft in the **N**ext **G**eneration
- TAPS III Combustor & Alternative Fuels
- FMS Technologies

FAA CLEEN Consortium
Public Plenary Session
MESTANG

Ken Creech
GE Aviation
May 4, 2016

Federal Aviation Administration

More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG):



Benefits:

More electric power and a light-weight power system to realize practical fuel savings and/or mission capability

- GE power system with improved performance at equivalent cost
- Leverages low-spool extraction
- Subsystems certified for retrofits before 2026

Objectives:

Mature an integrated aircraft power system consisting of a bleedless, dual-spool engine, and a second-generation more-electric primary power system

Work Statement:

- Component/subsystem validation
- Electric power system and integrated technology lab demonstration

Key CLEEN 2 Accomplishments:

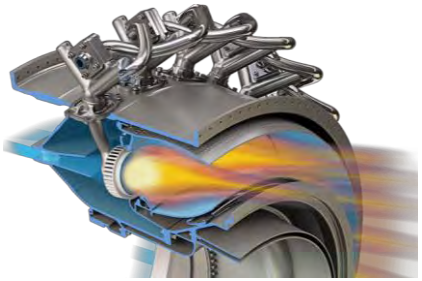
- Completed initial engineering trade studies for architectural layout
- Defined System Architecture with LRU descriptions
- Engaged the GE Global Research Center (GRC)
- Performed preliminary planning for Modeling & Simulation tasks

FAA CLEEN Consortium
Public Plenary Session
TAPS III Combustor & Alternative Fuels

John Herbon
GE Aviation
May 4, 2016

Federal Aviation Administration

GE TAPS III Combustor:



- Higher pressure
- Reduced cooling flow
- Advanced materials

CLEEN II:

- Improved premixer for <CAEP/12 NOx target
- Advanced modeling/design tools
- TRL6 Core Demo of emissions/performance

Benefits:

- GE9X projected SFC ~10% below GE90-115B
- LTO NOx >35% margin to CAEP/8 @ 55 OPR
- Mission cruise NOx reduction below SOA
- Low-NOx technology for application in highest OPR/largest engines; design tools/methods for scaling to future applications and engine cycles

Objectives:

Advance the development of next-generation low-NOx TAPS III combustor to TRL6

Work Statement:

- Establish baseline NOx / performance
- Develop technologies: Fuel injection, aerodynamic mixing, modeling tools
- Staged advancement to TRL6 via rigs & core engine demonstration

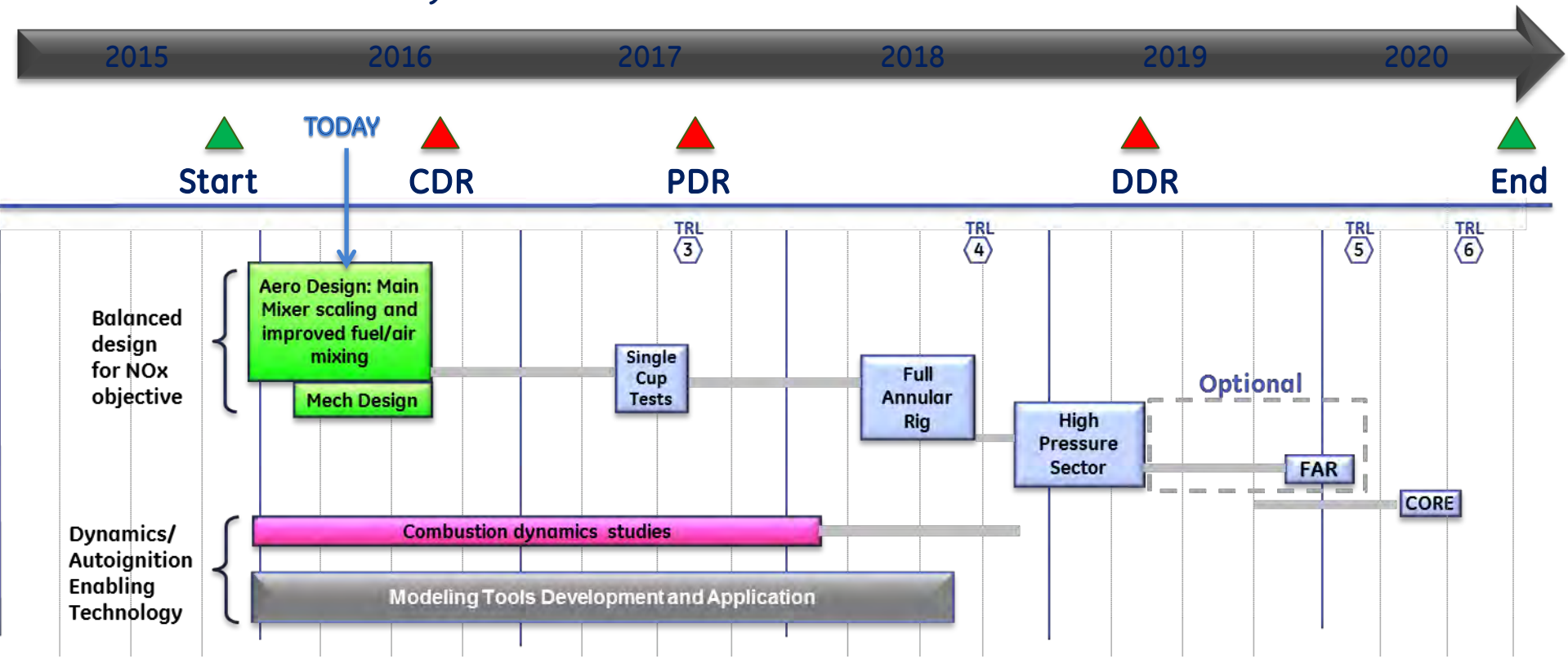
CLEEN II Progress since Nov. 2015:

- 3 adv. premixer architectures identified; CFD optimization in process
- 1st concept mixer built; screening test rig on-line
- Baseline: FAR1 test and 1-cup high T/P durability test complete; 1-cup acoustics mapping underway
- Combustion dynamics models being validated against rig data; applied to predictions of HP Sector and engine

GE TAPS III Combustion System Development

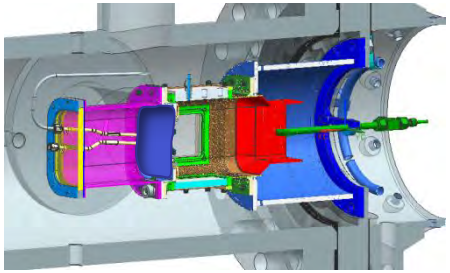
Goals and Schedule

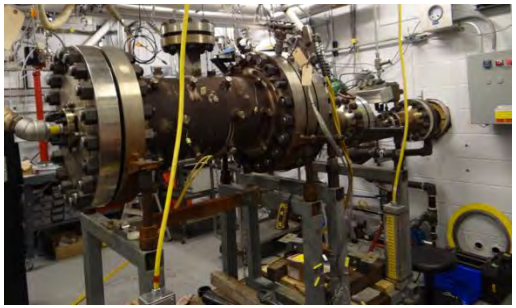
- LTO NOx emissions (FAA Goal) — 35% margin to CAEP/8 @ 55 OPR
  - Cruise NOx emissions (GE Goal) — < SOA
  - Solid Particulate Matter (GE Goal) — 60% margin to CAEP/6 (based on Smoke no.)
  - Combustor Durability (GE Goal) — Increased TOW



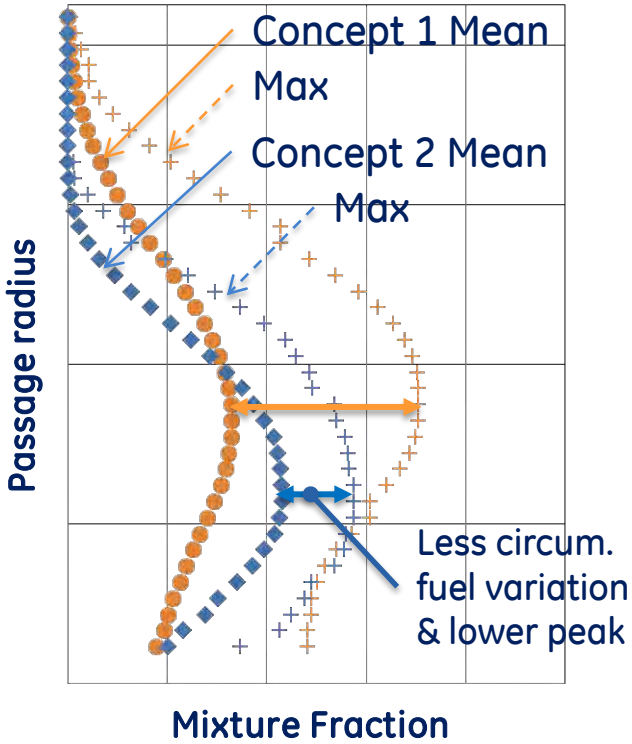
GE TAPS III Combustor Development – Activities

CLEEN II Test Rig @ GRC
250psia / 850F

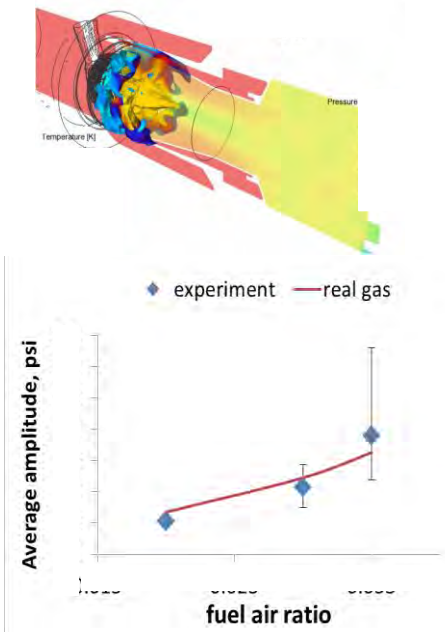




LES modeling of Adv Premixers



SED model of 1-cup rig



- Balanced design to enable further NOx reduction and engine system performance improvements

Alternative Fuels

Relevance, Impact, Approach, Capability

FAA/GE goals:

General:

Advance the approval and intro of "drop in" fuels

Specific:

1. Support ASTM D4054 – testing/demo phase
2. Conduct work complimentary to other FAA programs

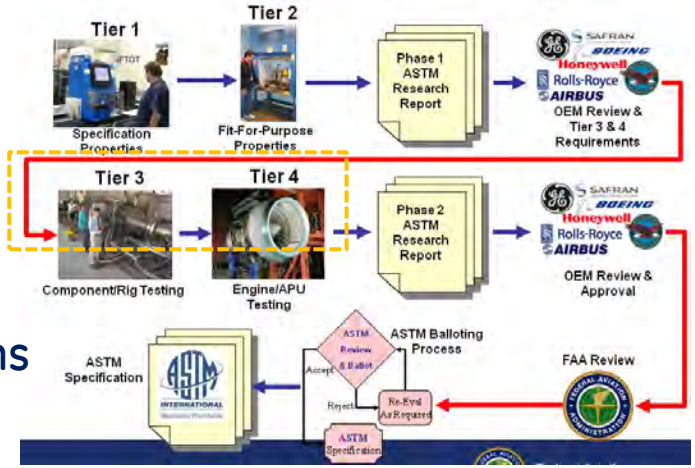
Plan against specific goals:

1. Test one fully synthetic fuel inline with ASTM roadmap; synergize w/ TAPS III effort (FAR & Core)

   Impact: advance the approval of real candidate fuel; extend further into lean combustor fleet

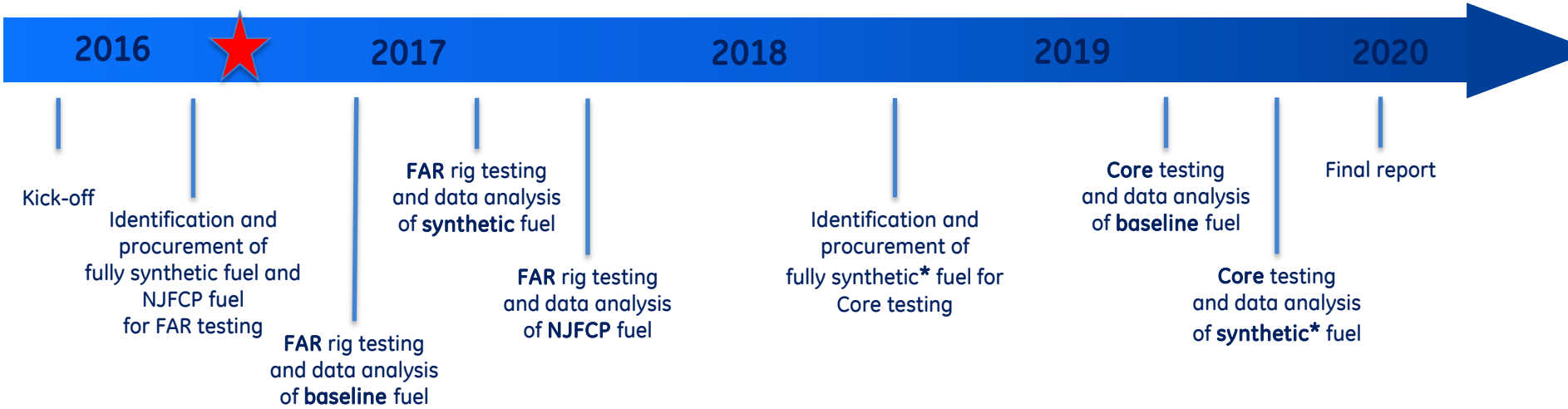
2. Test one "reference" fuel defined by FAA's NJFCP program; synergize w/ TAPS III effort (FAR only)

   Impact: demonstrate correlation between fuel effects at fundamental (NJFCP) and advanced (FAR) tests; gain insight to support approvals simplification



ASTM D4054

Alternative Fuels
Schedule



* A different synthetic fuel than the one for FAR test could be pursued for Core per learnings from the FAR test

CHJ (catalytic hydrothermolysis) fuel was selected for 100% synthetic fuel. Producer was identified. A letter of intent for 11000gal fuel procurement issued.

100% or a blend of ATJ-SPK seems to be best candidate for NJFCP fuel. Other OEM tests of various NJFCP fuels might make another fuel more attractive – *decision at NJFCP mid-year review in June!*

Federal Aviation Administration

FAA CLEEN Consortium
Public Plenary Session
FMS Technologies

David Lax
GE Aviation
May 4, 2016

Federal Aviation Administration

Expand on CLEEN I Technology in CLEEN II

GE provides an integrated **holistic approach to aircraft and engine optimization**, as demonstrated in CLEEN I.

CLEEN I Technology	TRL
Adaptive Engine Model	6
Optimum Climb Performance	6

CLEEN II Goal; Extend adaptive engine model and optimum climb performance technologies to enhance the full flight profile

Federal Aviation Administration

FMS efficiency improvements

Optimal Cruise

- ***What***: Fuel reduction in cruise phase by flying a tailored flight profile to minimize total cost of operating the aircraft.
- ***Why***: Legacy approach makes simplifying assumptions to the cost function, leaving unclaimed benefit
- ***Status***: Underway

Wind Optimization

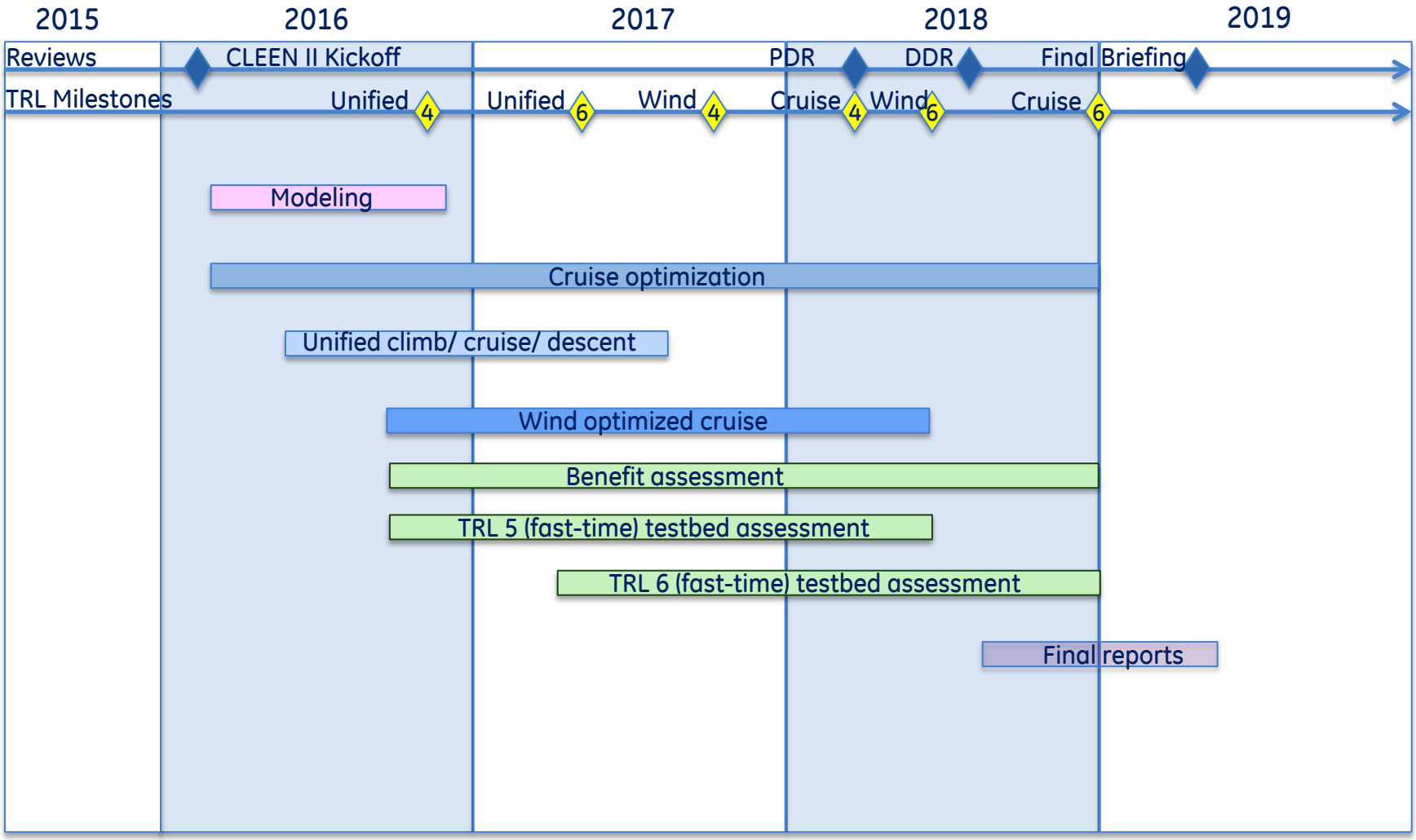
- ***What***: Fuel reduction by flying through favorable winds
- ***Why***: Wind impact on direct operating cost is large.
- ***Status***: Not started

Unified Climb, Cruise, Descent

- ***What***: Fuel reduction by optimal transition between climb, cruise, descent
- ***Why***: Transitions used today are simple to calculate, but cost more.
- ***Status***: Not started

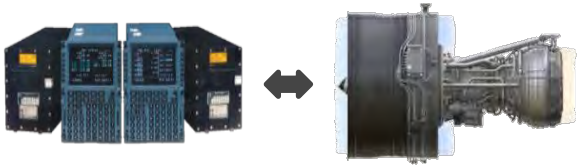
Federal Aviation Administration

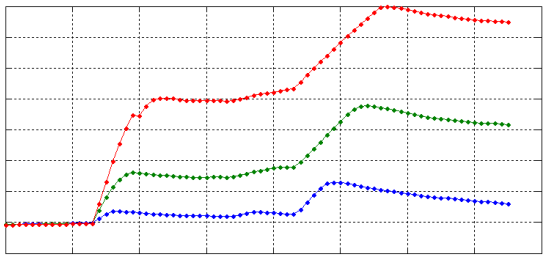
CLEEN II Program Status Schedule



Federal Aviation Administration

Cruise Optimization





Benefits:

- Opportunities to extend technology into cruise phase and realize savings over legacy system:
  - Better knowledge of engine impact on cost function
  - Algorithm advances enabled by faster processors to remove optimization constraints

Near-term plan:

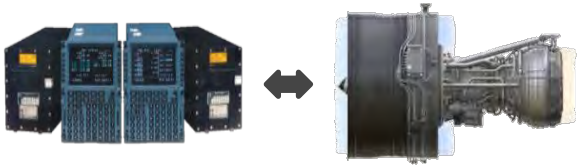
- Continue to develop simulation environment used for TRL 5 benefit assessment.
- Develop automated testing scripts to validate TRL 6 software modules.
- Continue to refine cruise optimization algorithm through conceptual development phase

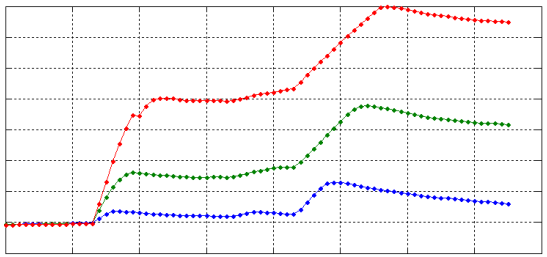
Accomplishments /Milestones:

- Risk Reduction solver module developed to TRL 4.
- Preliminary entitlement results captured

TRL 4

Unified Climb, Cruise, Descent





Benefits:

- Investigate potential fuel savings that may be achieved by performing optimal transitions between climb, cruise, and descent phases of flight.
- Investigate breaking constraints inherent in legacy flight phases to achieve an overall optimal 4DT

Near-term plan:

- Start concept evaluation in Q2 2016

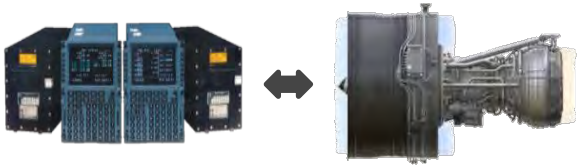
Accomplishments /Milestones:

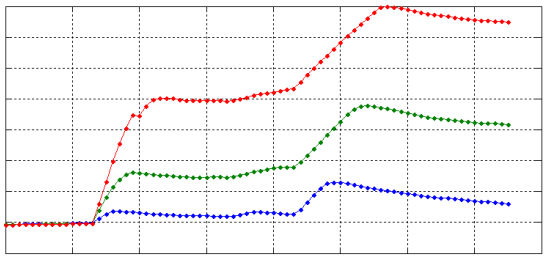
- Not started

Starting 2016, Q2

Federal Aviation Administration

Wind Optimization





Benefits:

- Opportunities to leverage additional wind information in the cost function to minimize fuel usage.

Near-term plan:

- Start concept evaluation in Q4 2016

Accomplishments /Milestones:

- Not Started

Starting 2016, Q4

Federal Aviation Administration