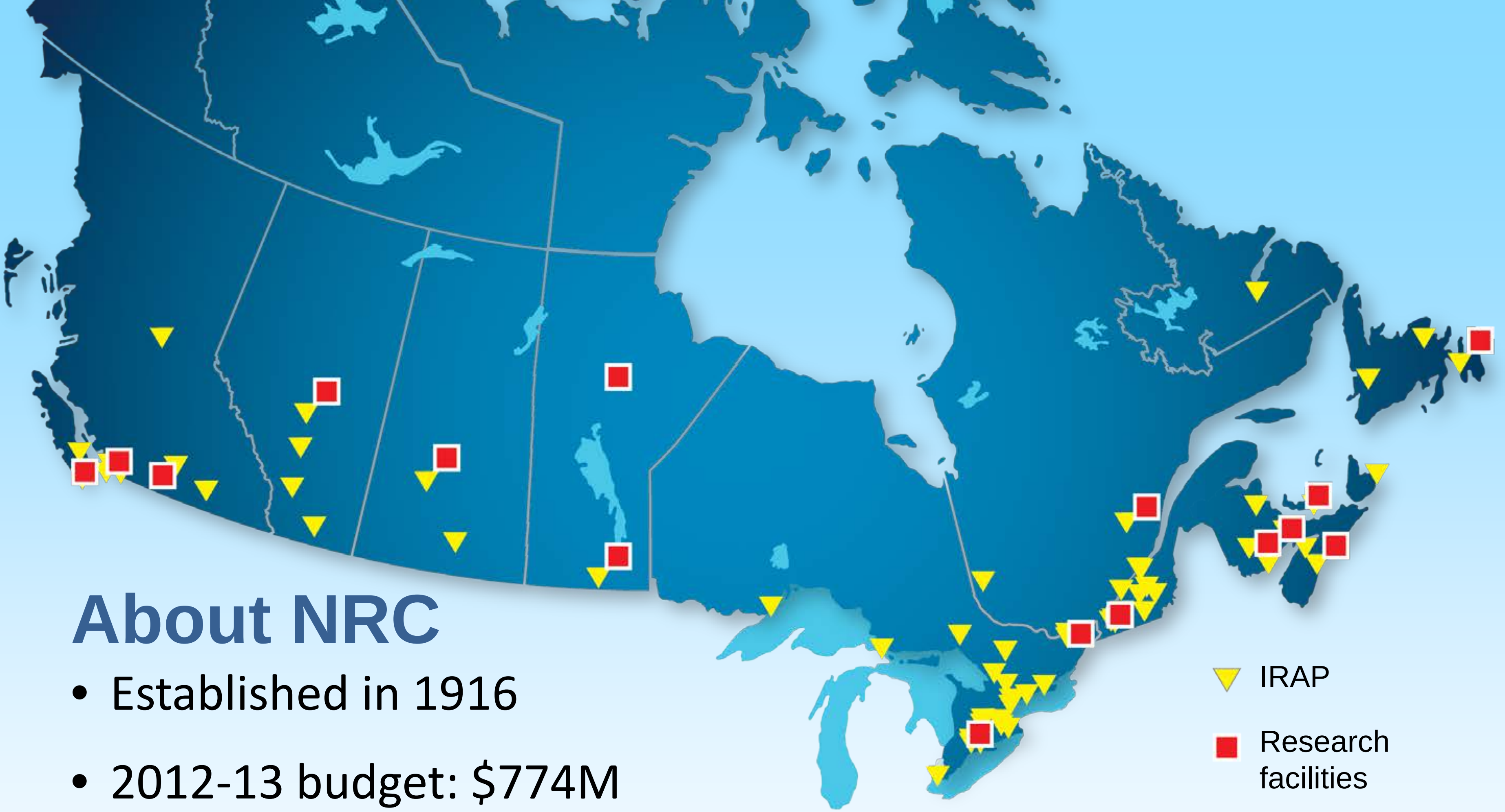
Alternative Fuels to 100LL Aviation Gasoline

Wajid Ali Chishty and Pervez Canteenwalla
NRC Aerospace

March 18, 2014





About NRC

- Established in 1916
- 2012-13 budget: $774M
- Over **3,700** employees and 650 volunteer and independent visitors
- Supporting industry in wide variety of disciplines and through broad array of services

Organizational Structure

DIVISIONS / PORTFOLIOS

Emerging Technologies

- Information and Communications Technologies
- Measurement Science and Standards
- National Science Infrastructure
- Security and Disruptive Technologies

Engineering

- Aerospace
- Automotive and Surface Transportation
- Construction
- Energy, Mining and Environment
- Ocean, Coastal and River Engineering

Life Sciences

- Aquatic and Crop Resource Development
- Human Health Therapeutics
- Medical Devices

Industrial Research Assistance Program

- Pacific Region
- West Region
- Ontario Region
- Quebec Region
- Atlantic & Nunavut
- National Office

Common Services to support portfolios and IRAP

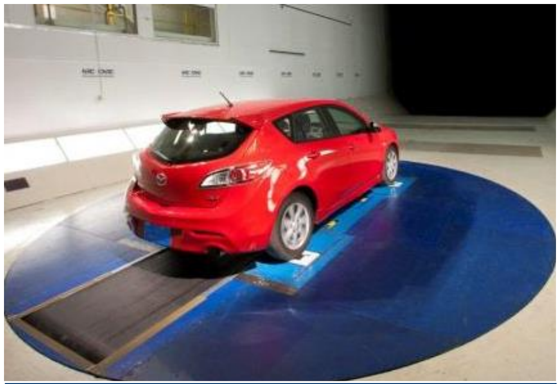
NRC Aerospace

- Serves as primary aerospace research division for other Canadian government departments:
  - Transport Canada
  - Department of National Defence

- Provides large-scale infrastructure and technology foresight through strategic R&D and technical services

NRC·CNRC

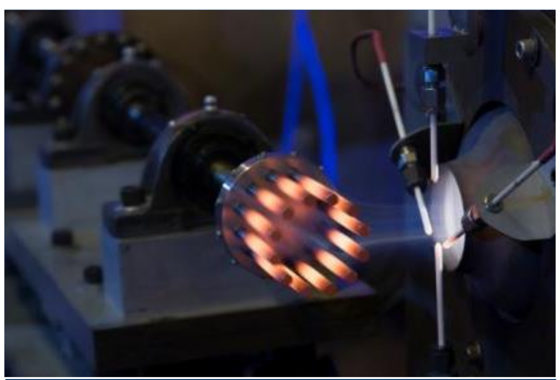
NRC Aerospace Competencies



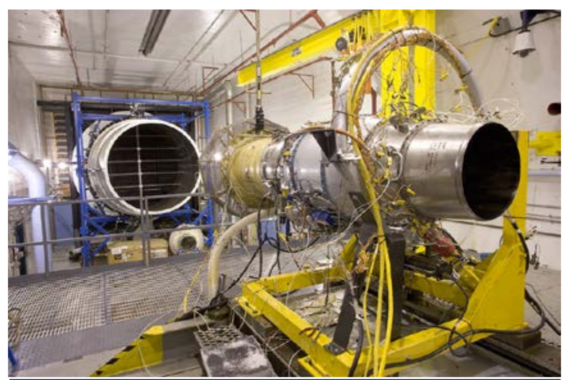
Aerodynamics

Manufacturing

Flight Research



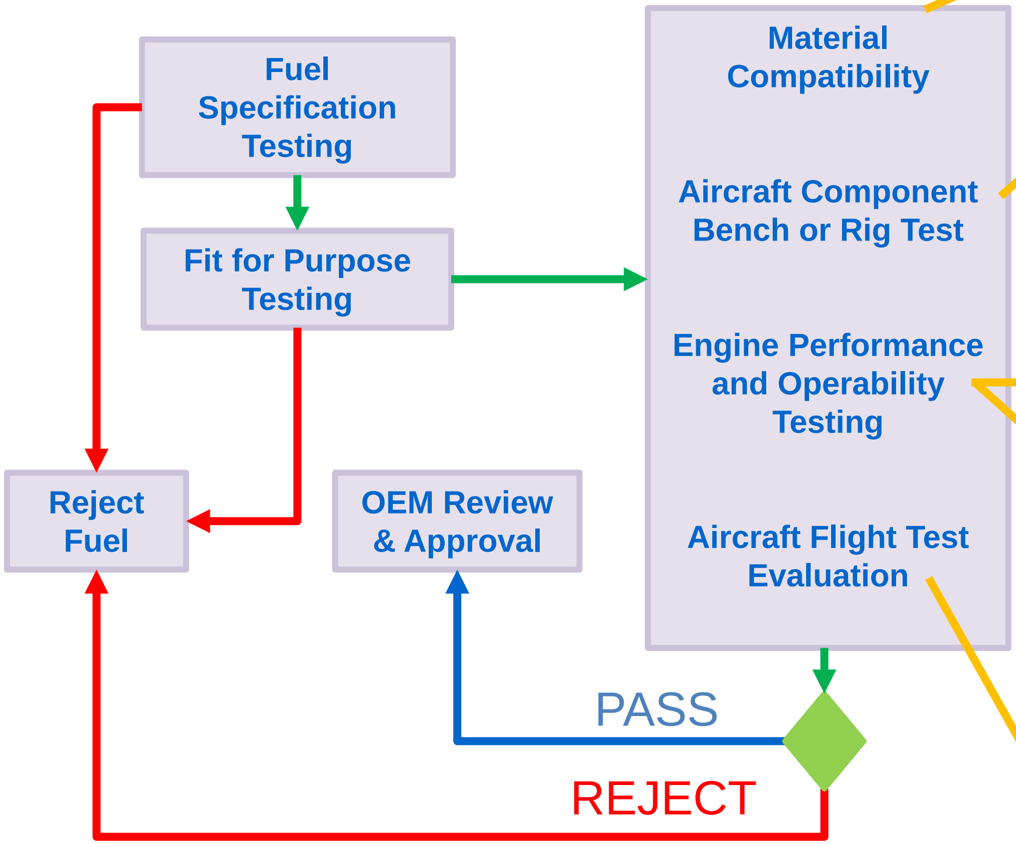
Structures and Materials



Propulsion and Power

Fuels Qualification

ASTM D7826 Fuel Qualification Protocol




Fuel Performance Evaluation


Cold/Hot Start, Relight, Engine Performance, Detonation, and Emissions


Material Compatibility

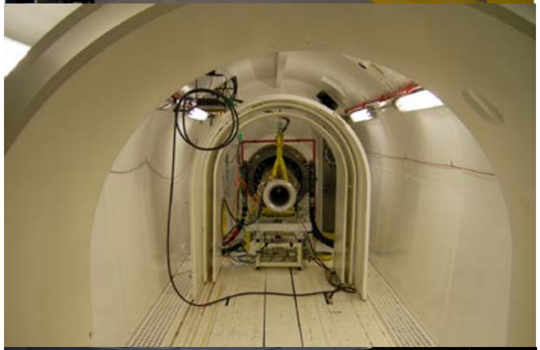

Engine Performance, Operability, Durability, and Emissions


Aircraft Performance, Operability, and Durability

Altitude Test Facility

Length x internal diameter	10m x 3m (32.5 ft) x (9.8 ft)
Maximum flow rate	10 kg/s (22 lb/s)
Minimum altitude	925m (3k ft)
Maximum altitude	15,850m (51.5k ft)
Ambient minimum altitude (non-refrigerated moist air)	92m (300 ft)
Minimum temperature at a flow rate of 2 kg/s (4.4 lb/sec)	-48.3 °C (-55 °F)
Minimum temperature at a flow rate of 4.5kg/s (10 lb/sec)	-25 °C (-13 °F) -35 °C (with LN2)
Heated inlet air at a flow rate of up to 2 kg/s (4.4 lb/sec)	+48 °C (+118 °F)

- 1000+ channels for analog inputs @ 50Hz
- 100+ channels @ 100kHz
- Gaseous and PM emissions measurement capability
- Capability to handle ICE, turbofan, turbojet, APU, etc



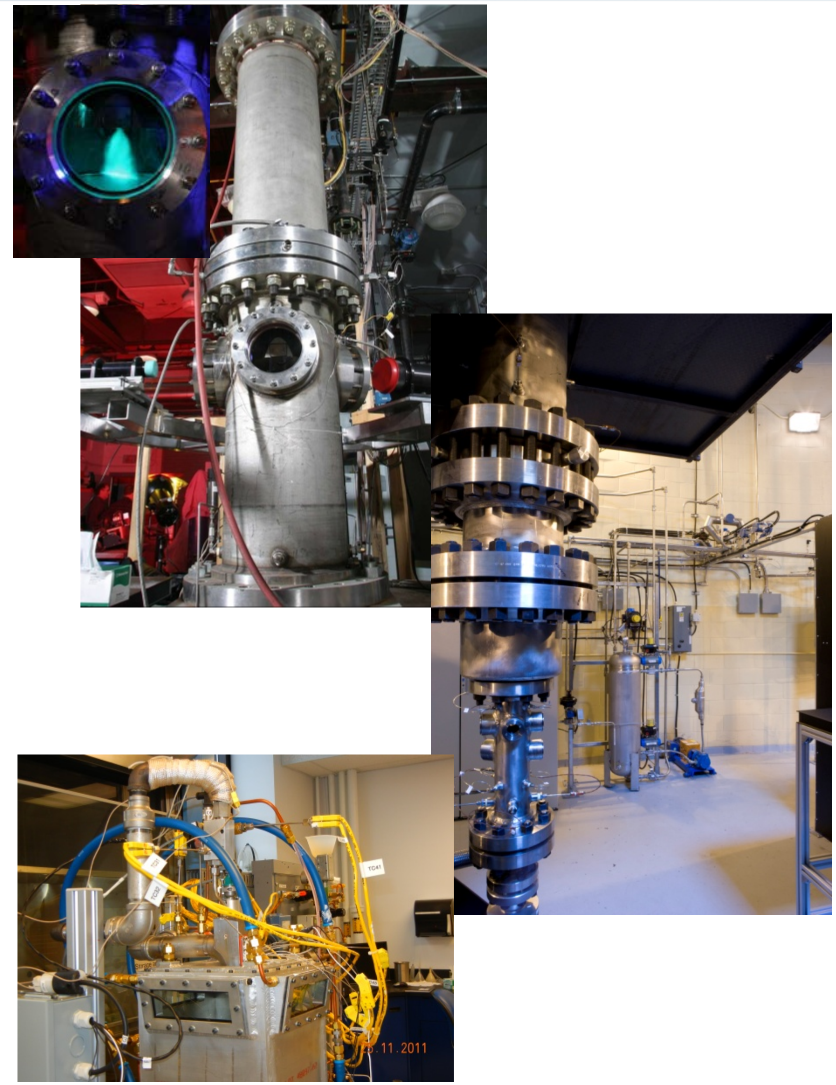
NRC·CNRC

Other Facilities Relevant to Fuel Qualification

- Optically accessible injector sector rig for spray characterization
  - 20 bar (300 psig), 4.5 kg/s air delivery
  - FN, drop sizing and velocity, laser sheet imaging
  - Laser diagnostics (PDPA, PIV, Malvern)
  - 3-D traverse system

- Optically accessible single injector sector rig for heated fuels analysis
  - 35 bar (515 psig), 475^{o}C capability
  - Nitrogen sparging system
  - Laser diagnostics (PLIF, PIV, LSD, Malvern)

- Vaporizer rig for investigating the fouling propensity of transportation fuels



NRC·CNRC

Alternative Fuels to 100LL Project

- Project aims to gather experimental data to assist in qualification and certification of 100LL avgas replacement fuels

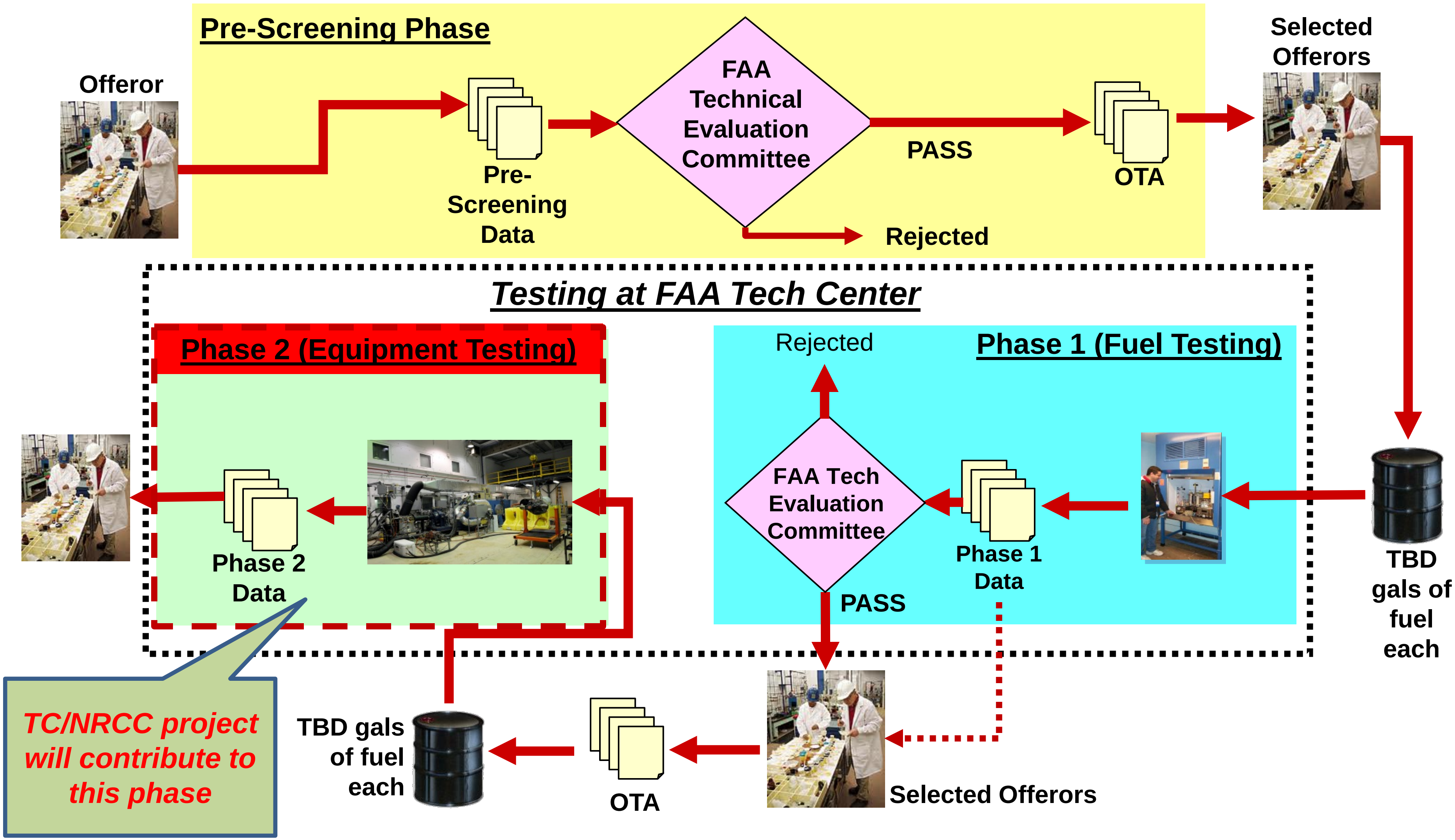
- Jointly initiated and partly funded by Transport Canada (TC) and National Research Council (NRC)

- Government of Canada Clean Air Agenda:

  "*…find ways to reduce airborne pollutants as a result of air transportation*" (NRC and TC are both signatories to this policy)

- Coordinate with US FAA and PAFI

Canadian Project Link to US PAFI Program



Project Objectives

- **Static Engine Testing (2013 – 2016)**
  - To fill in the present knowledge gap that is imminently required for the qualification and certification of unleaded alternative fuels for general aviation
  - To conduct due diligence for the qualification of the next stage of the campaign i.e., flight testing.

  These objectives will be met through engine performance (including detonation and vapor lock) and emissions measurements at test cell simulated altitudes using a well-accepted high-compression engine platform representative of the general aviation fleet.

- **Flight Testing (2015 – 2017)**
  - To evaluate fuel performance under operational usage
  - To evaluate long term operability and durability

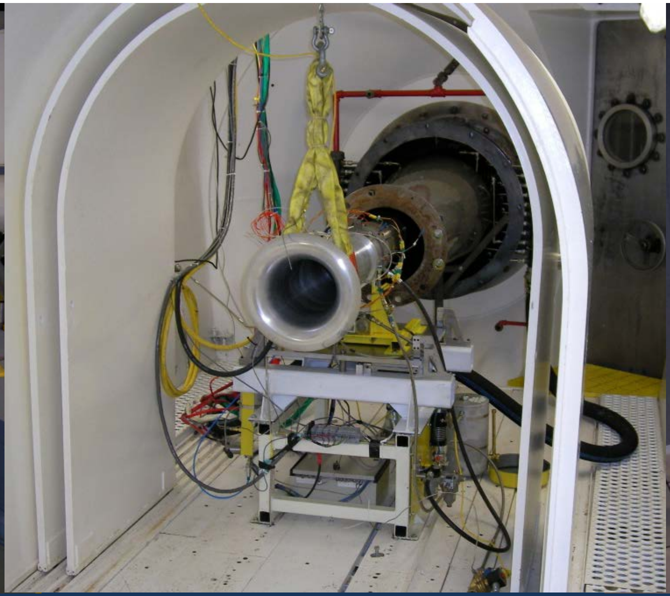
  These objectives will be met through extensive flying cycles (200 hrs/year) on an instrumented twin engine aircraft and recording performance data. Engine wear and tear will be evaluated through teardown inspections post every cycle.

Static Engine Testing (2013 – 2016)

- **Sea Level Testing (2013 – 2015)**
  - Setup and commissioning of skid-mounted engine test bed in consultation with FAA and engine manufacturer
    - Acquire engine, dynamometer, data acquisition, spare parts, etc.
  - Conduct testing on baseline and three candidate alternative fuels
  - Validate results with FAA database

Altitude Static Engine Testing (2015 – 2016)

- Use aircraft piston engine rig in NRC's Research Altitude Test Facility
- Test experimental alternative fuels to 100LL in controlled simulated altitude environment to investigate effects on:
    - Engine performance (power, knock, vapour lock, etc.)
    - Engine operability (cold starts, altitude relights, etc.)
    - Engine wear
    - Engine emissions



Flight Testing (2015-2017)

- Commission twin-engine aircraft at NRC's Flight Research Laboratory using same engine as in Static Engine Testing

- Test candidate alternative fuels to 100LL in actual flight conditions to correlate results from Static Engine Testing

- Operationally test effects of fuel energy content, distillation, material compatibility, lubricant compatibility, miscibility, and storage stability.

NRC·CNRC

Funding Requirements

- Static Engine Testing

Phase 1 – Planning & Setup	$109,000
Phase 2 – Commissioning	$1,441,000
Phase 3 – Testing	$1,124,000
Estimated Budget	**$2,674,000**

(Partial funding secured from TC and NRC)

- Flight Testing

Estimated Budget	**$3,000,000**

(No funding currently secured)

Breakout Sessions Logistics

- Three groups
- Random assignment to a group (check your nametag)
  - **Group 1: Yellow** – Go to 2nd Floor Conference Room
  - **Group 2: Green** – Go to Room S303
  - **Group 3: Red** – Stay in the Council Chamber (this room)
- Each group will provide a “Champion” to summarize findings
- Groups will discuss topics (on next slide) until 3:30pm
- Coffee Break: 3:30pm-4:00pm
- Will reconvene at 4:00pm and each Champion will present a summary from their group

Breakout Session Agenda

1) What aspect of 100LL replacement is of primary importance to your organization?

2) This morning we presented a multi-stage project relating to 100LL replacements. Do you generally agree with proposed approach? Is there something to add or change?

3) Are there interim measures you consider viable (e.g. use 100VLL, UL94 with no ethanol, etc.)?

4) TC and NRC are committed to supporting this project. Additional partners are being sought. Is your organization interested in being a partner and supporting this work? If so, what form of support do you envision (e.g. direct funding, in-kind contribution, advocacy)?

Thank you

Wajid Chishty
Program Lead
Tel: 613-993-2731
wajid.chishty@nrc.ca

Pervez Canteenwalla
Research Officer - Propulsion
Tel: 613-990-0652
pervez.canteenwalla@nrc.ca

Malcolm Imray
Airworthiness Engineer
Tel: 613-990-4484
malcolm.imray@nrc.ca