Instrumentation Challenges and Wireless Sensor Opportunities at the NRC Flight Research Laboratory

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Outline

Background:

Projects: Instrumentation, Simulation & Modeling techniques.

Challenge:

Wired sensors but very little wireless capabilities, Wireless sensors – mainly in airdata sensors.

Test Aircraft Available:

Data fusion using AI, plug-n-play instruments.

NRC Aerospace mandate:

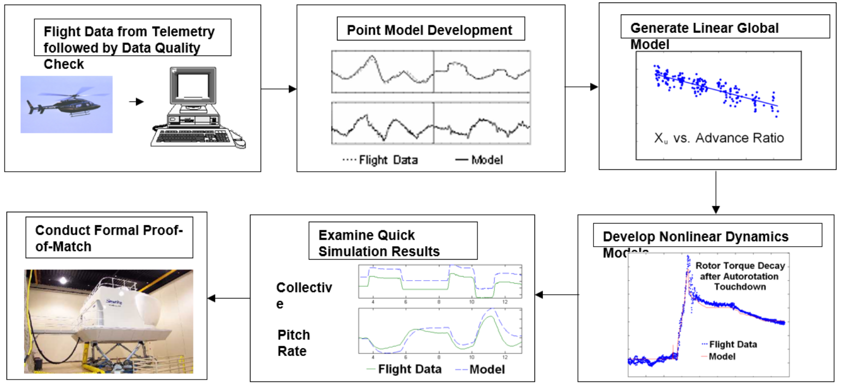
Digital Twin - High fidelity modelling, Real-time modelling, icing models and Integrated Autonomous Mobility.

Conclusions.

Projects

30 years of experience in Instrumentation, Flight Test Technique, Modelling and Flight Simulator Certification.

- Over 40 Fixed-Wing and Rotorcraft were flight tested and developed about 10 Level D flight simulators.
  - Assisted CAE to World #1 flight simulator manufacturer and training – (FT techniques, S&M-tech trans, Inst. and cert.)
  - Assisted BA for airdata system on C-series airplane (moisture resistance radome)
- Reducing flight simulator time to market (TruSim), Twin Otter Series 400 .
  - Viking sold over 100 aircraft simulators, over 500 options, in Canada and globally.
  - Europe alone bought 300+ aircraft.



Instrumentation

Wired Parameters Measured

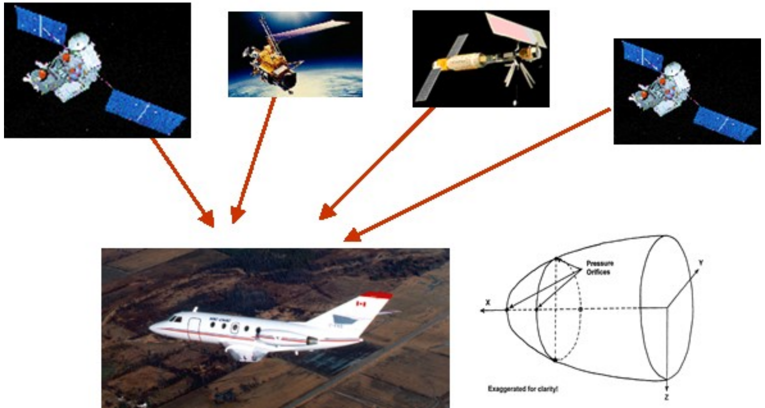
Control surface positions, Pilot control positions

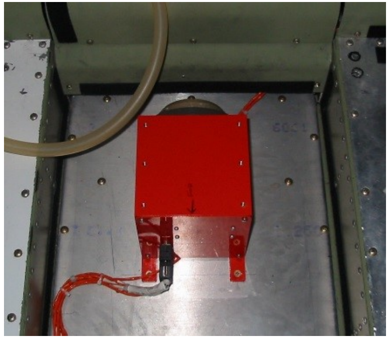
Pilot control forces, Inertial Navigation System

Angles of attack and sideslip, Pitot static for airspeed and pressure altitude

Engine parameters, Differential GPS position data

Air Data Systems Calibration

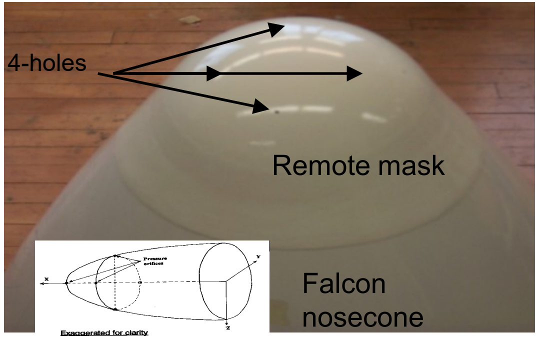


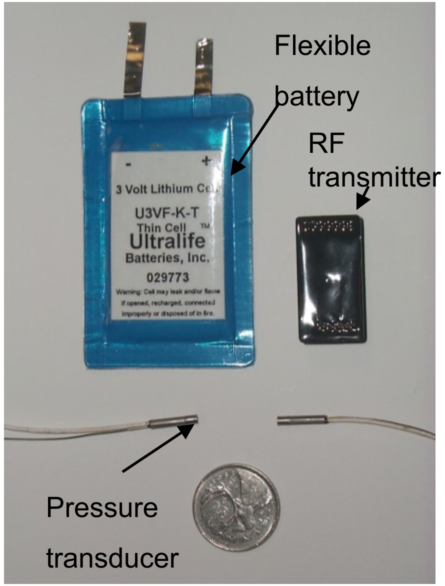


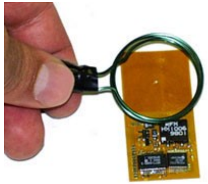
Wireless RF
Nose Mask

Wireless Work Innovative Remote Mask - to Measure Angles of Attack and Sideslip

Composite mask, RF transmitter, flexible battery and pressure transducer

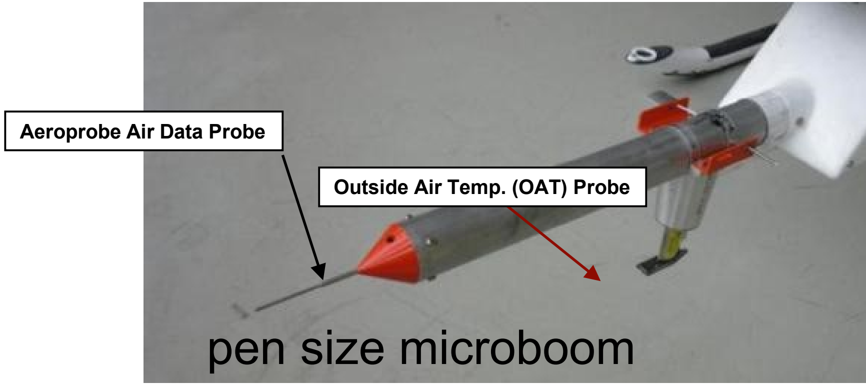


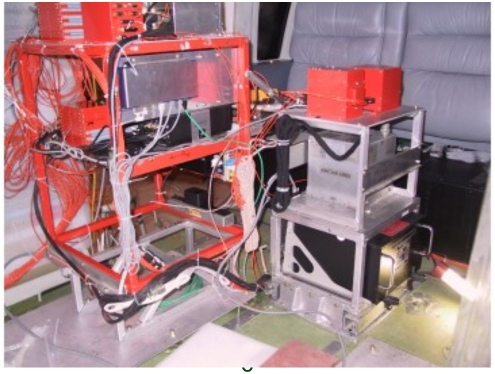




Challenge Signal Drops

MicroBoom on Bell206 and huge boom on Chinook – Air data boom Research





The accuracy of the calibrated angles of attack and sideslip as influenced by rotor downwash effects during manoeuvres

15 feet huge boom

Challenge huge boom + wiring

Flight test Program

Three dedicated flights:

- •First - air data systems calibration
- •Second – all axis 2311 control input manoeuvres for flight model development and
- •Third – qualify flight simulator manoeuvres.

Developed flight test techniques:

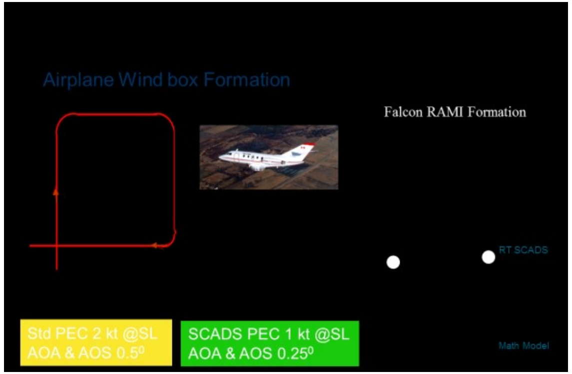
-In-flight Propulsion System Identification;

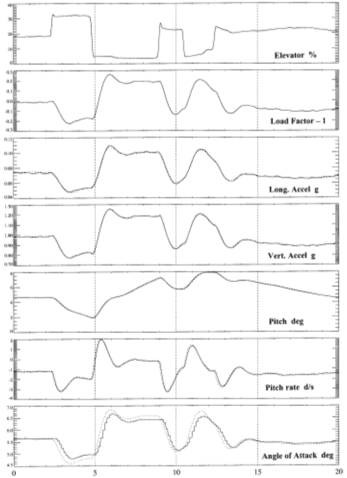
-Reversible flight control system identification;

-Inertia identification;

-Video recognition;

-Real-time model identification.



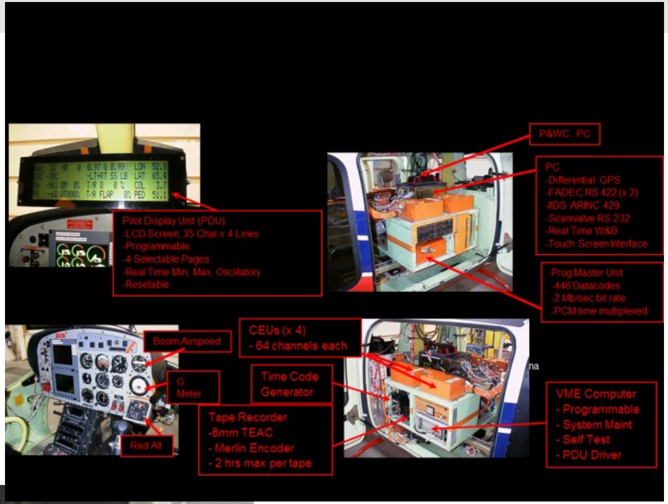


NRC Falcon 20 Longitudinal Response in 175 Knots and at 10500 ft

NRC Falcon 20 Research Aircraft

Data Fusion

FDR - data are accurate but sample rate is low;
Video – wireless data and data quality is low-obstruction, glare and vibration.
Artificial Intelligence – combine these data in an optimal way



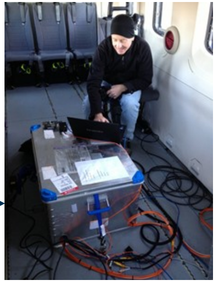
Sikorsky S-92 and Nextant 400XT: Flight Test Data Collection for Simulator Model Development

- *<u>Project Descriptions</u>:* Use of new video recognition technology and innovative glass cockpit ARINC429 capabilities to enable the collection of flight test data for the development of high fidelity full flight simulators

S-92 project – nonintrusive sensor

video

non-intrusive sensors



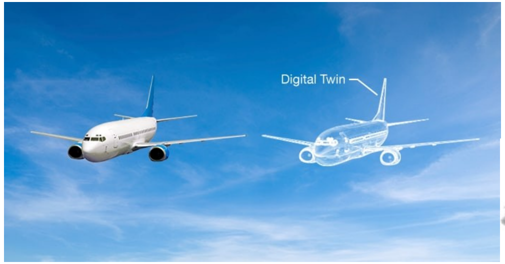
Challenge - Lens, signal drops

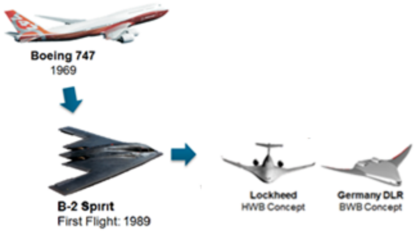
Nextant project – glass cockpit digital bus

Challenge – A/W

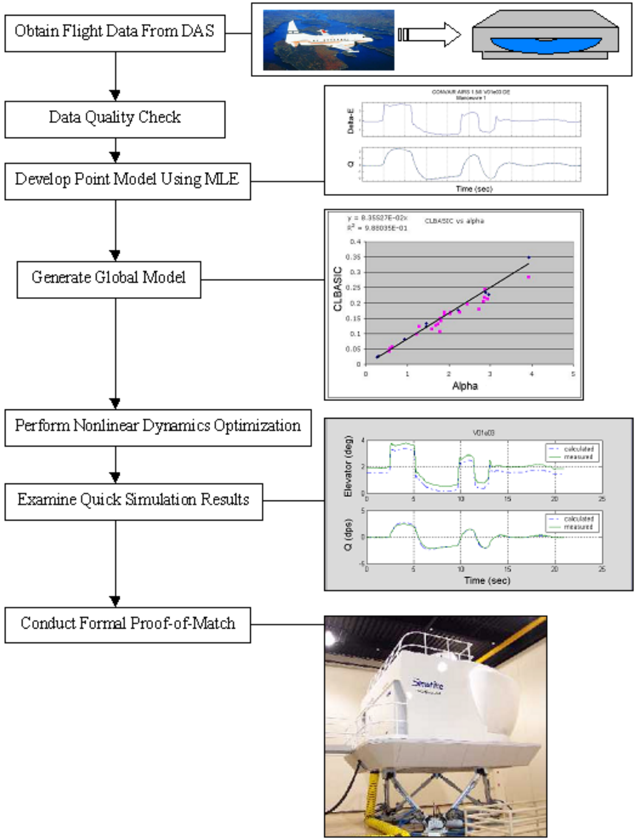
Strategic Development (5-10 years)

- NATO Aims for High-Fidelity Rotorcraft Modelling Leading to Digital Twin Capability.
  - Digital Twin Development for Digital Virtual Flight Test and certification.
  - Reduce development cost and time of aircrafts.
- Disruptive aircraft configuration.
  - Up to 15% fuel savings.
  - The disruptive aircraft configuration allows optimal performance.
  - AI is applied to optimize the disruptive aircraft control surfaces to increase control power.
- Air Taxi for Air Mobility
  - Develop High-Fidelity Simulations and autonomous control systems.
  - Similar to Aphid Development (From manned to unmanned arctic surveillance aircraft) to enhance Air Mobility.





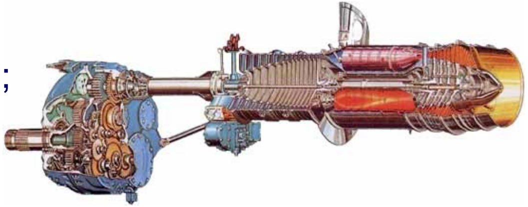
RAMI System Flow Diagram



NRC Falcon 20 Research Aircraft

Digital Engine Model

- Rolls-Royce Allison 501-D13 turboprop engines;
- Hamilton-Standard 4-blade propellers;
- Engine model (Series III T56 A15) was derived by the Canadian Forces Technical Office and NRC's Structures Materials and Propulsion Laboratory;
- Used OEM's 54H60 propeller model;
- Engine performance model was validated with the OEM's drag data.

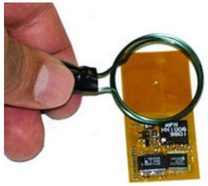


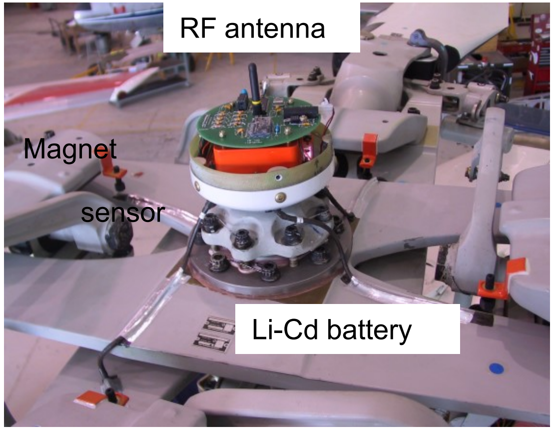
Allison 501 turboprop engine

Hamilton-Standard 4-blade propellers

Innovative Remote Sensor to Measure Flapping Angles

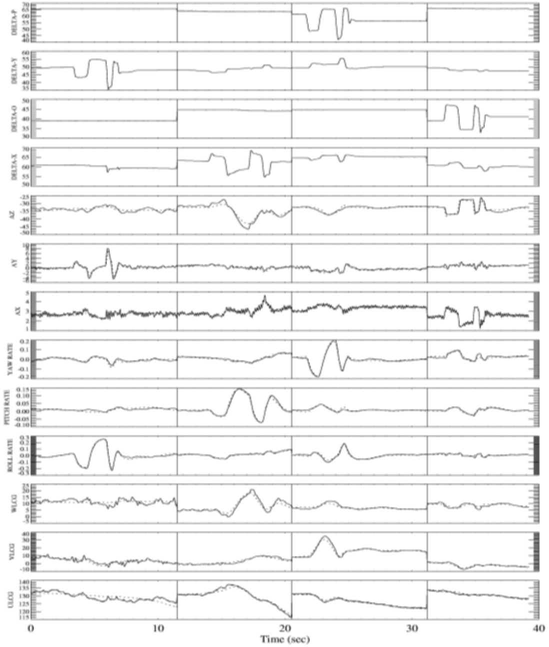
- Composite cover
- RF transmitter
- 9 volt battery
- Hall effects magnetic sensor





Aerodynamic Model Development and Validation – 80
Knots Flight Manoeuvre

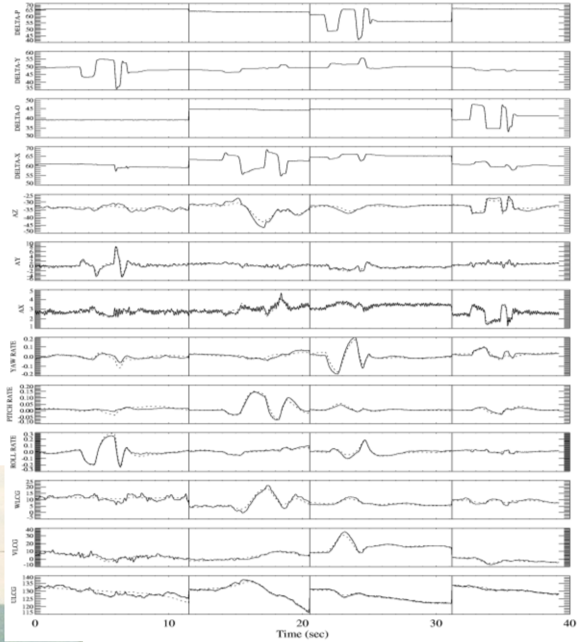
Point Model Development



4 sets – 2311 control input manoeuvres

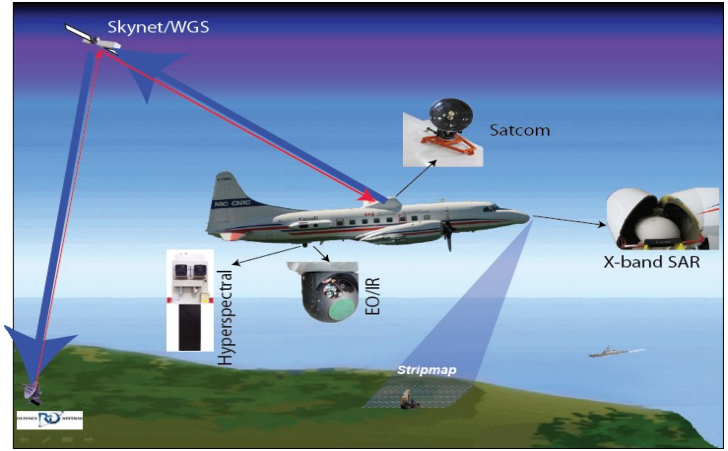
Helicopter

Flight Model Validation



Same 4 sets of manoeuvres

NRC Convair Sensors



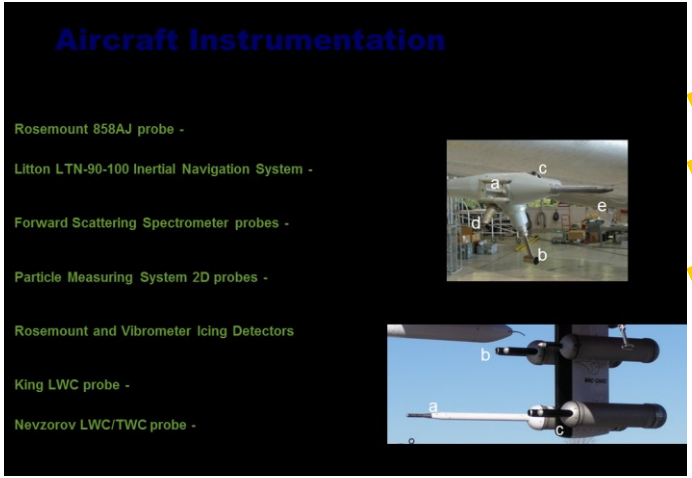
- **Environment:**
- Extensive in-situ and remote sensing sensors that can be used to assess performances of wireless systems in various weather conditions

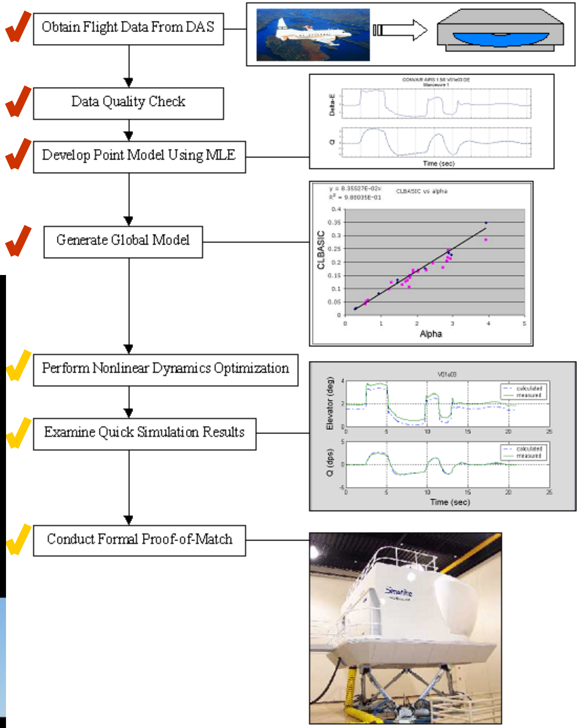
- **ISR**
- State-of-the art capabilities for earth observations, target detection and secured communications
- Platform can be used for testing and evaluating performance of wireless technologies compared to proven system already integrated on the aircraft

Overview of Aerodynamic Modelling Technique

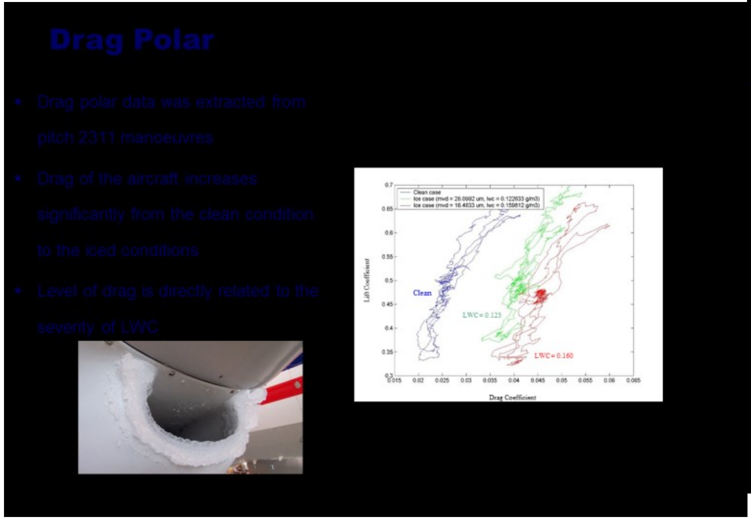
1. **Flight data, data quality, point model and continuous model**

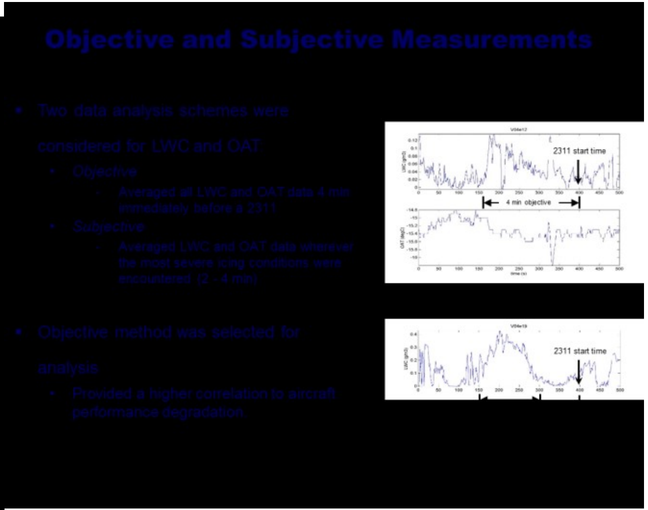
2. **Non-linear dynamics, Icing cloud microphysics data, Global model, model validation**





Icing Sensor Measurements and aircraft model

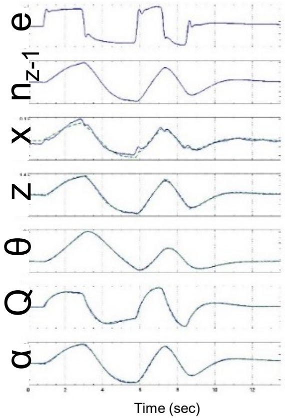




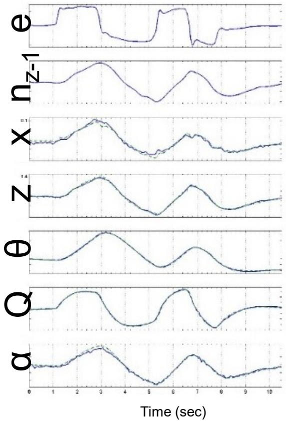
Co-relate airplane and icing parameters

Point Model Identification Results

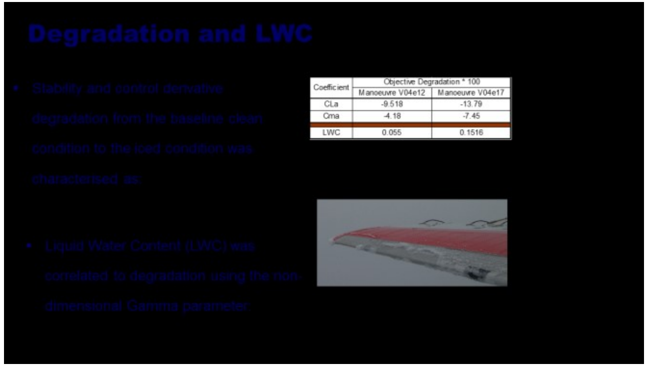
- A collection of aerodynamic derivatives found with MLE at a trim condition forms the point model
- Longitudinal elevator (e) responses produced an excellent point model match



Clean condition identification results



Iced condition identification results



Icing parameters relates clean and icing models

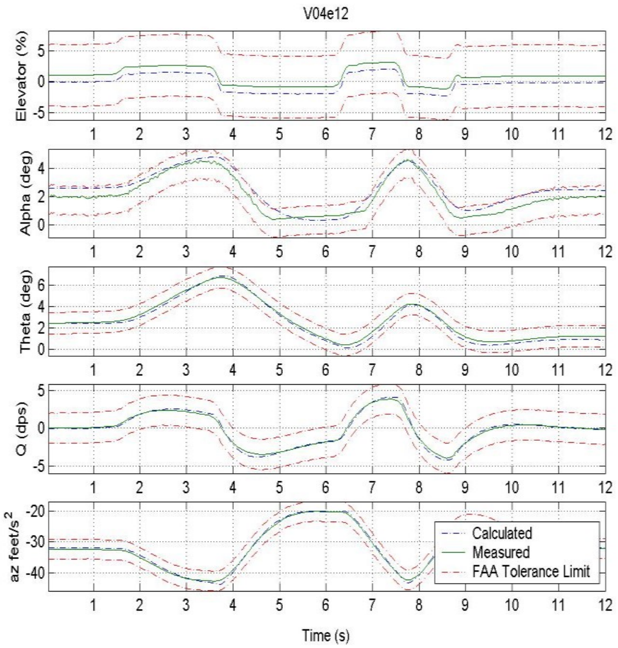
flight data ———
model response - - - - -

Icing Model Validation - POM

Icing model was validated using the Proof of Match technique:

- LWC, OAT, TAS were input into the icing model using the Gamma parameter;
- Degraded stability and control derivatives were derived;
- Derivatives, and aircraft initial conditions

Calculated response falls within the FAA Part 60 Tolerance Limits



Proof of Match output for a longitudinal elevator response

TRex 700E UAV Development

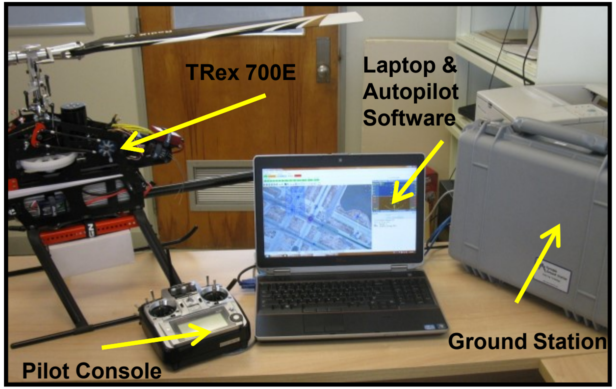


Figure 1: Complete System Set-up

Overview:

- The TRex 700E is an RC helicopter equipped with both a **Piccolo Autopilot System** and a **Data Acquisition System.**
- This set up (**Figure 1 & 2**) is currently being used for the development of a high fidelity aerodynamic model as well as tuning gains for the control laws.
- This test bed has the software- and hardware-in-the-loop capabilities. This is a digital virtual flight test platform.

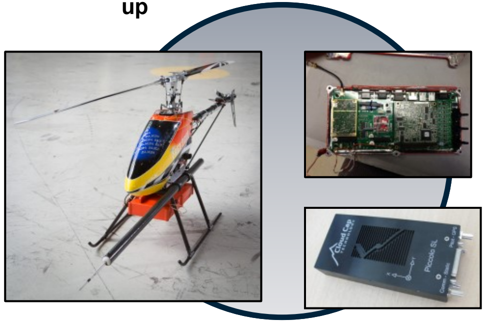


Figure 2: TRex 700E, Data Acquisition System & Autopilot

Manned-Helicopter to UAV

- Instrumented with:
  - Novatel SPAN-SE-D dual antenna receiver system.
  - Honeywell HG1700AG58 IMU.
  - Flight control system.
- The flight control computer was used to log actuator position. This actuator position was transformed into collective and cyclic pitch angles.
- This instrumentation suite would produce high fidelity data for modelling.
- The Trex capability transferred to Aphid

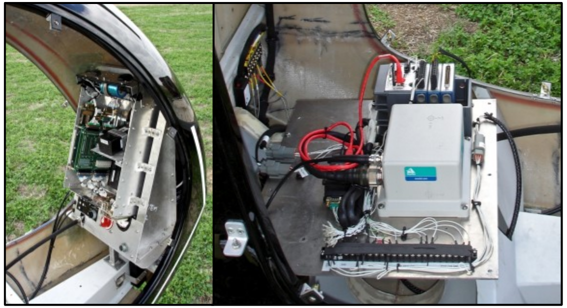


Figure 3: Flight Control System (left) & Novatel SPAN-SE-D with Honeywell IMU (right)

Figure 4: Aphid Landing Skids (left) & Main Rotor (right)

Canada's Aphid helicopter soars to new heights – National Research Council

Aphid is a computer-controlled flight system that allows the helicopter to safely take off on its own, perform maneuvers via remote control and then return to an automated state for self-landing.

Arctic Surveillance

Certified Ground Control Station

Conclusions

NRC flight test and modelling techniques have been developed over the last 30 years and are now mature.

Wired sensors work, but tedious; limited wireless sensors have been developed/used at FRL.

Within the next few years, a new strategy is required to develop digital Twins, Integrated autonomous mobility and other capabilities. Wireless sensors will be a part of the new innovation.