Validation Ice Crystal Icing Engine Test in the Propulsion systems Laboratory at NASA Glenn Research Center

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PSL Icing Session Summary

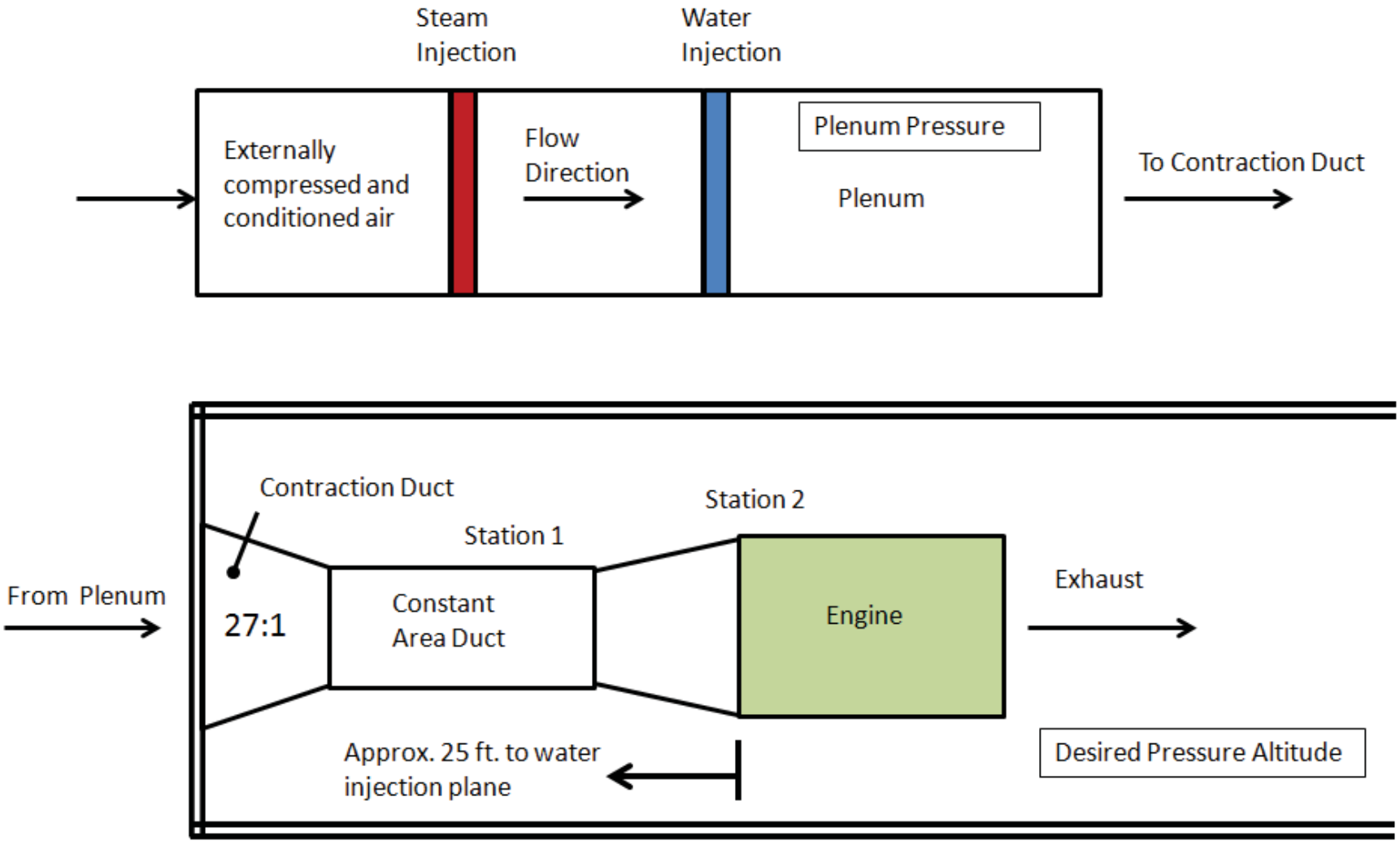
Time	Topic	Presenter
0930 – 1000	Turbofan Ice Crystal Rollback Investigation…	Goodwin / Honeywell
1000 – 1030	PSL Icing Facility Upgrade Overview	Griffin / NASA
1030 – 1100	PSL Ice Crystal Cloud Calibration	Van Zante / NASA
1100 – 1200	**Validation Ice Crystal Engine Test**	**Oliver / NASA**
1200 – 1230	Modeling of Commercial Turbofan Engine…	Veres / NASA

Presentation Overview

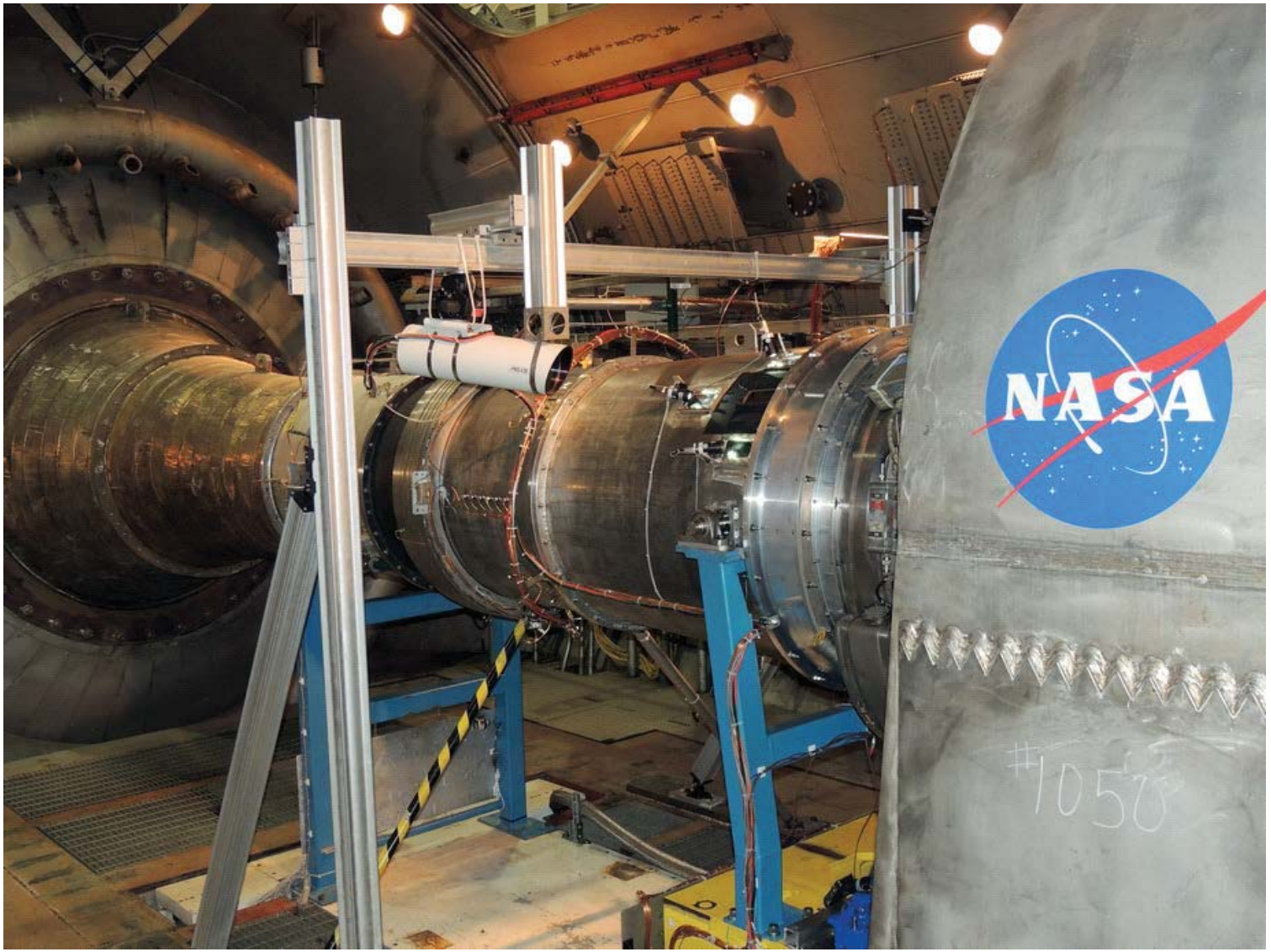
- Test Facility: Propulsion Systems Laboratory (PSL)
- Test Article: ALF502-R5
- Test Objectives: Primary, Secondary, Additional
- Additional Test Observations

Propulsion Systems Laboratory
NASA Glenn Research Center, Cleveland, OH

Propulsion Systems Laboratory Test Cell Three (PSL-3) Schematic Icing Configuration

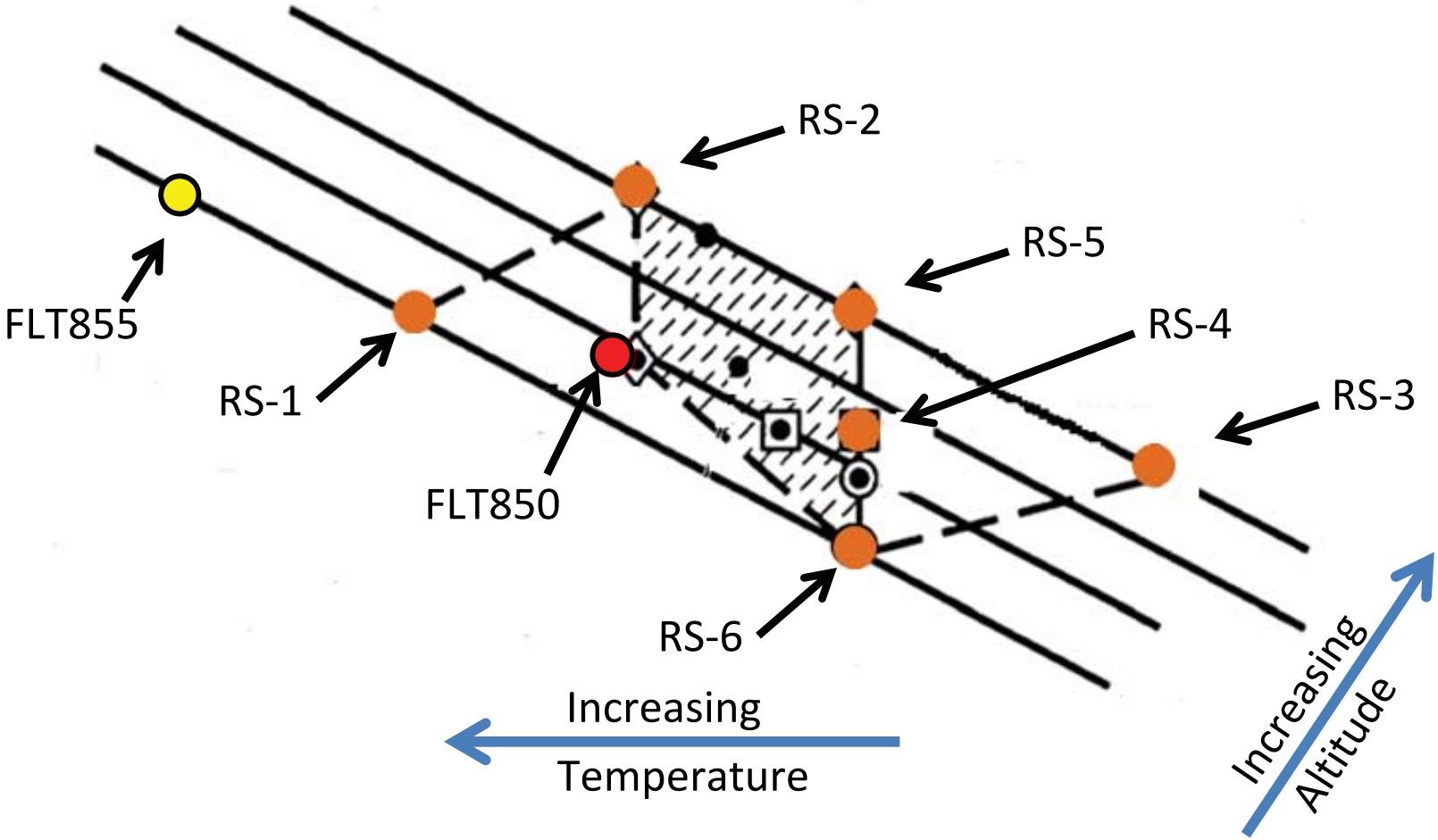


Inaugural Ice Crystal Icing Engine Test Rig in PSL-3

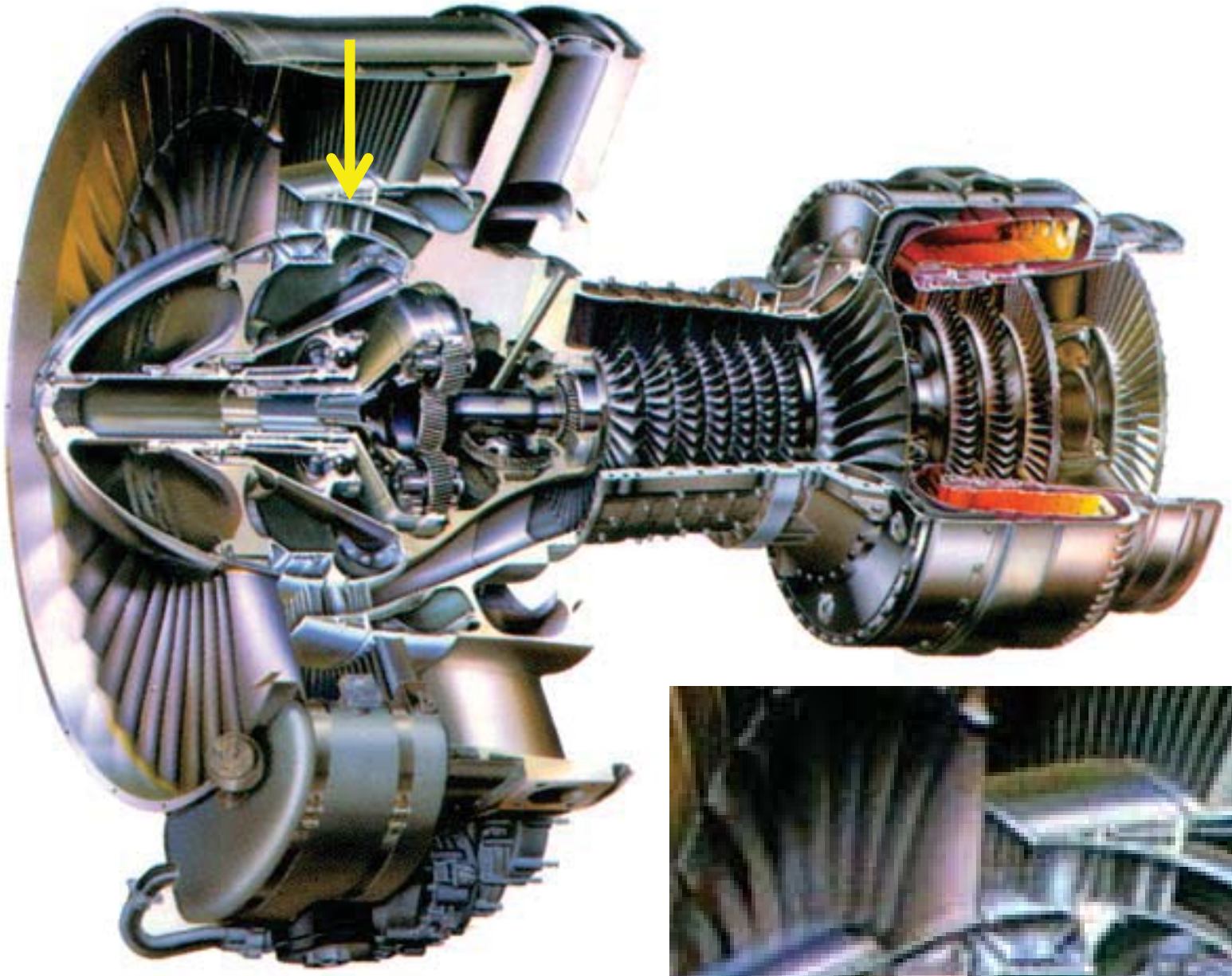


ALF502-R5 Installed on a BAe-146 aircraft

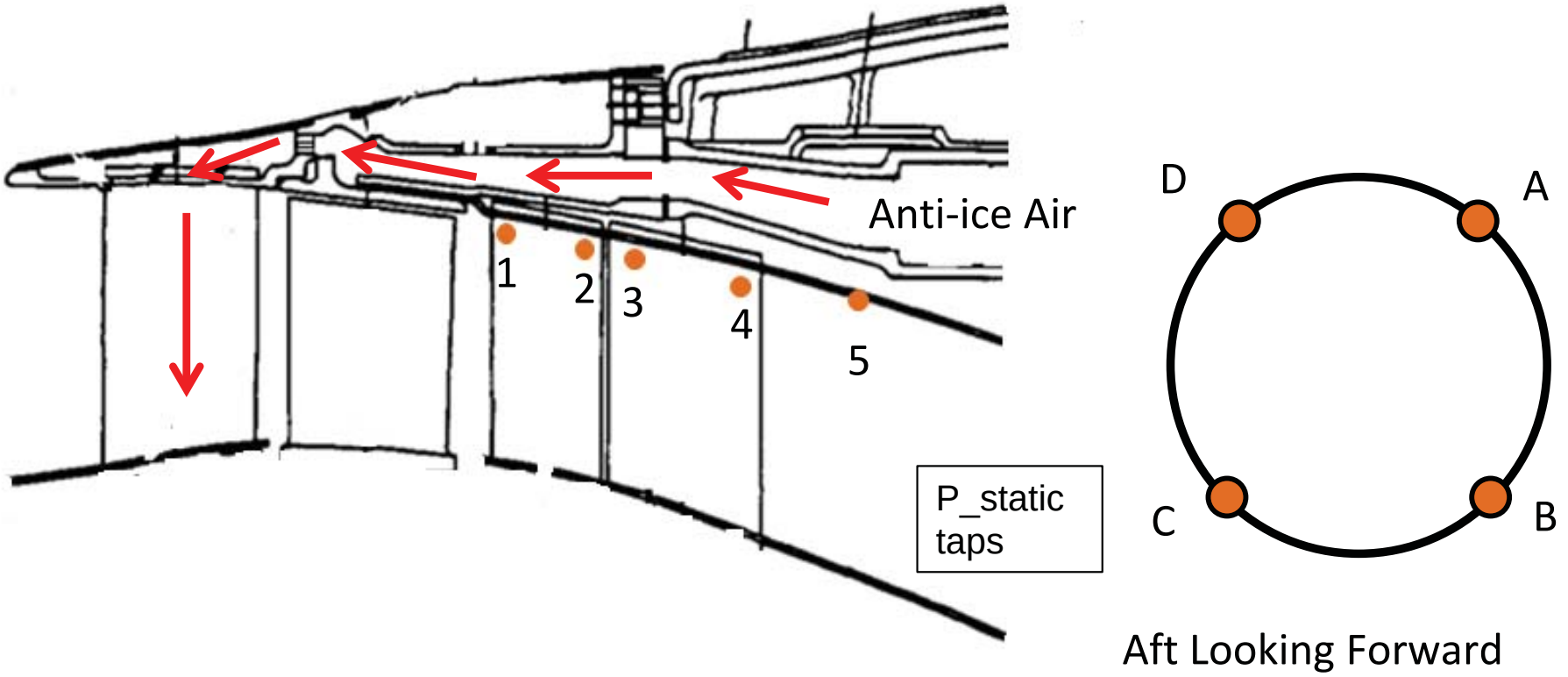
Revenue Service Field Events
1997 Flight Test Points
Test Points Conducted in PSL Feb. 2013



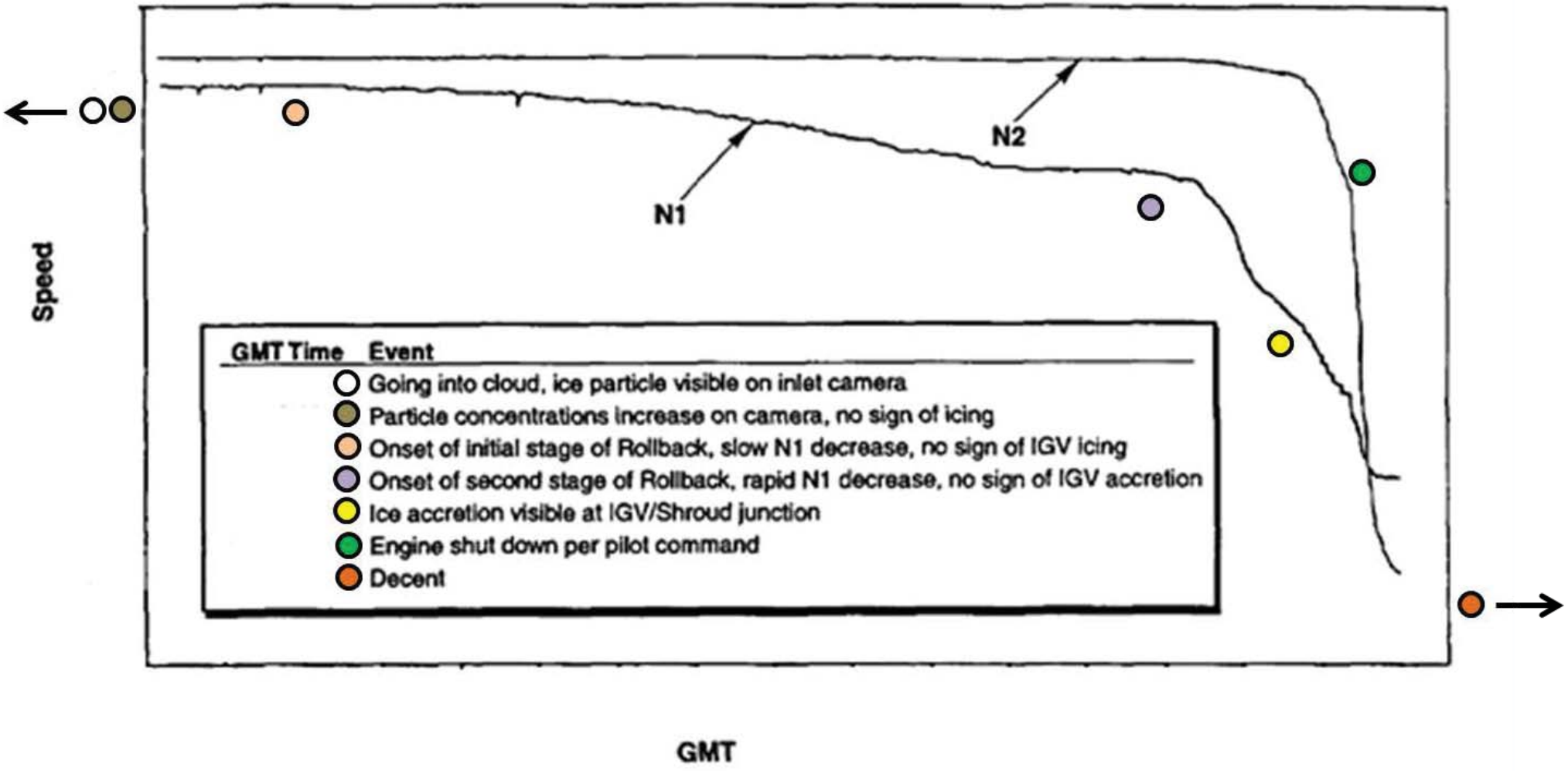
Engine Cut-away View



LF01 Internal Flow Path Instrumentation



FLT850 Roll back of ALF502-R5 (LF01) During 1997 Flight Testing



1997 FT 850 Flight Test Video of Roll back showing IGV ice accretion

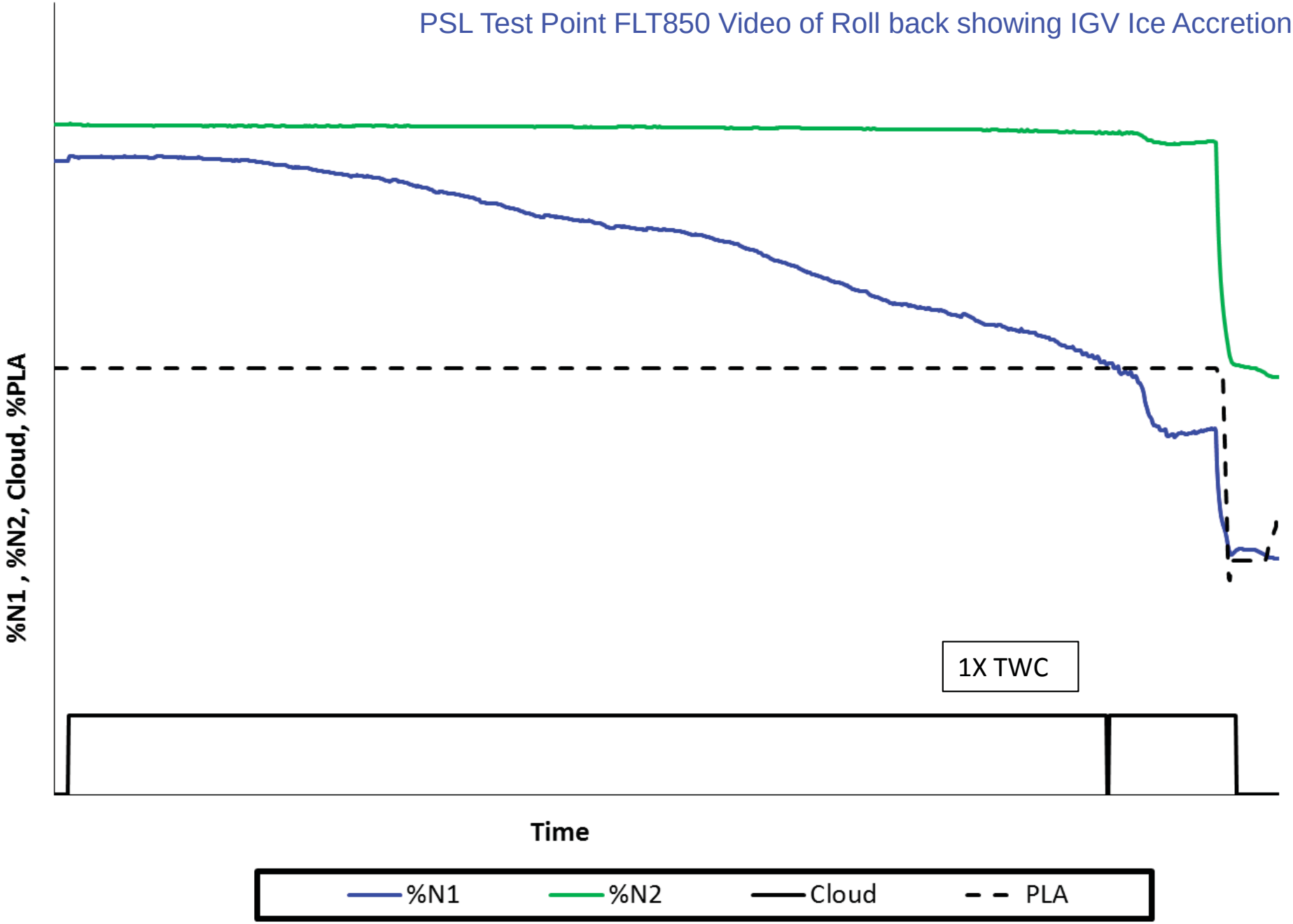
Primary Objective: Achieved Successfully

Calibrate and Reproduce known significant 1997 flight test points:

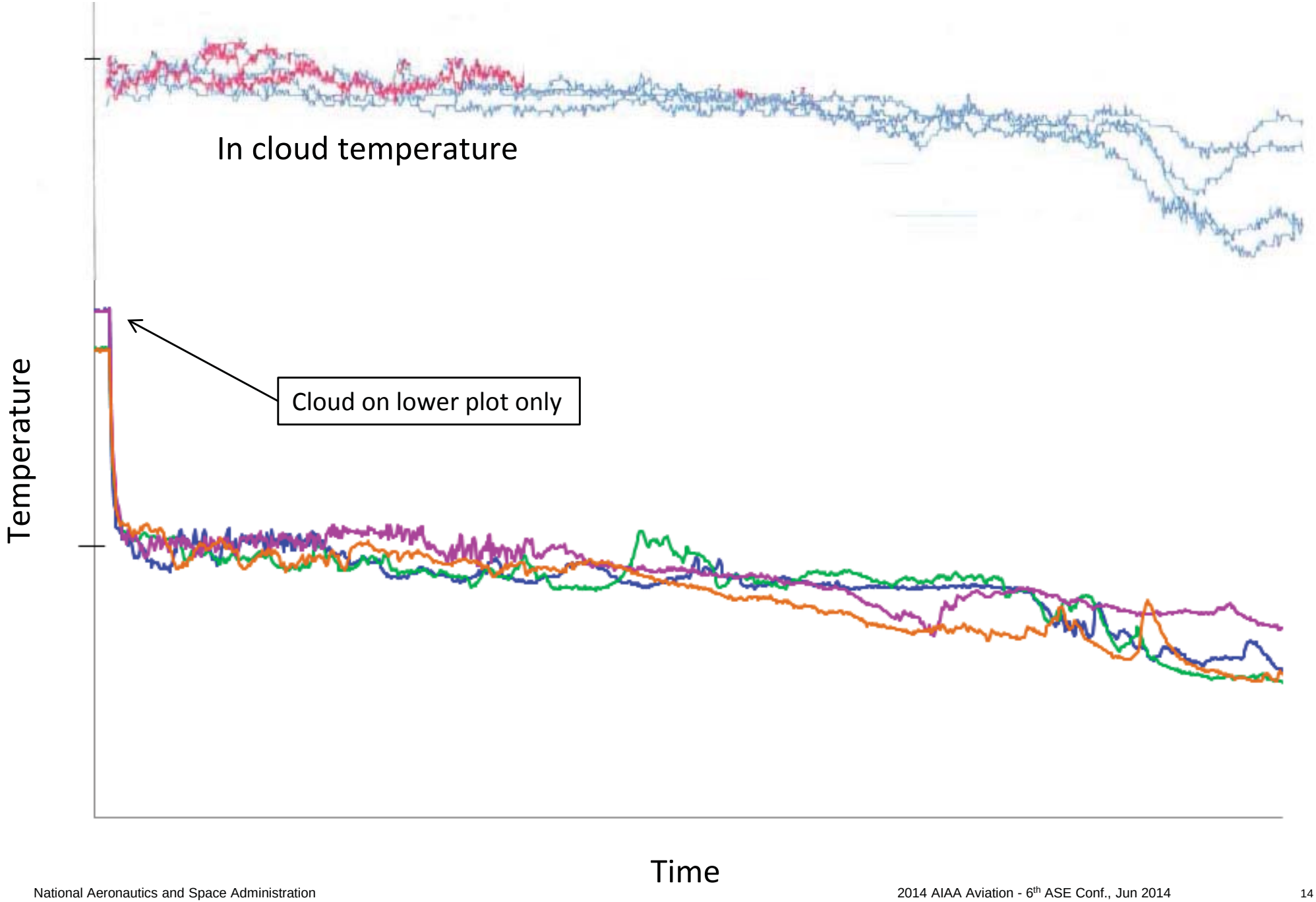
1. FLT 850 (Roll back)
2. FLT 855 (No Roll Back)

FLT850 Fan, Compressor, Throttle and Cloud Traces

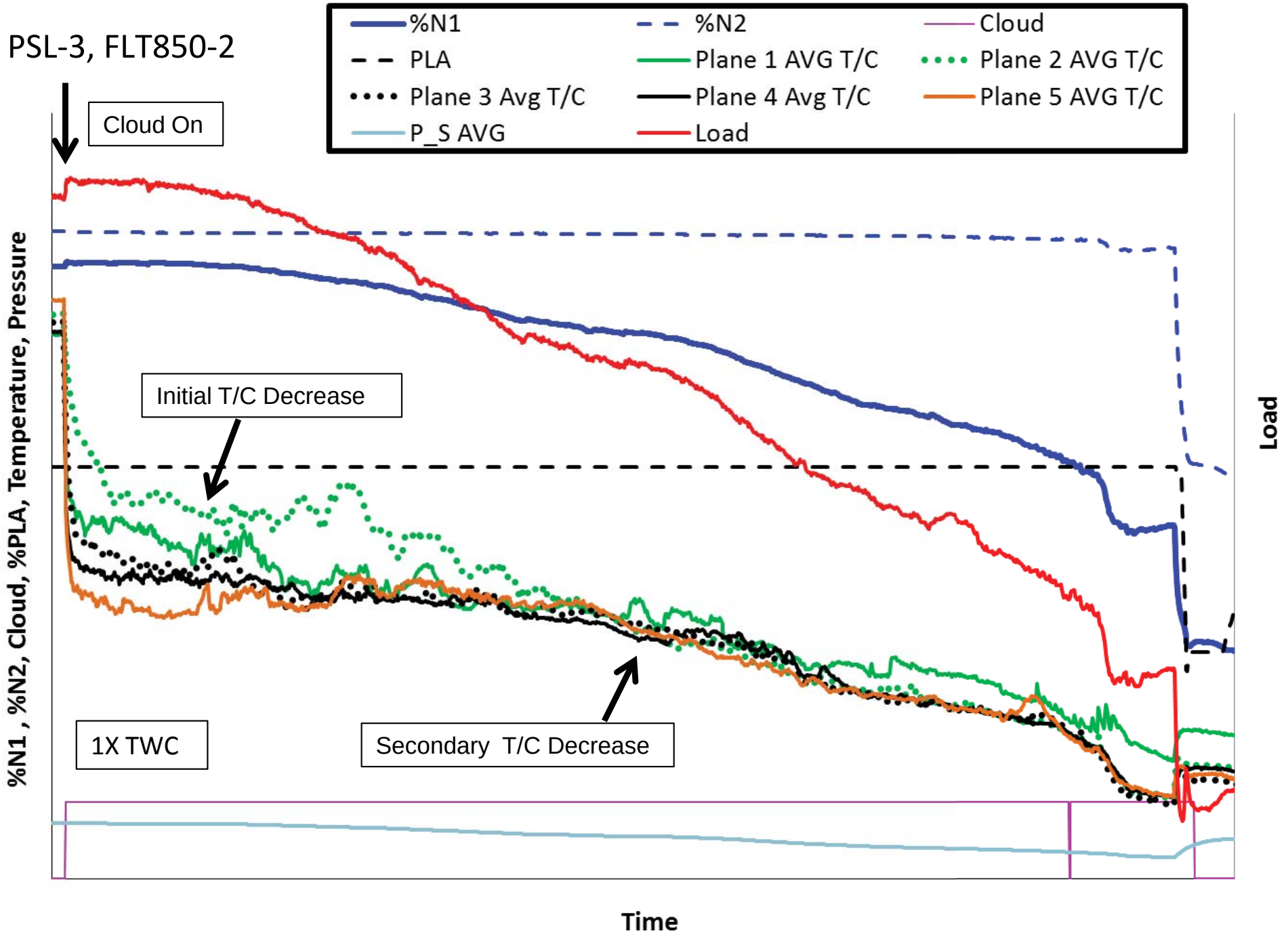
PSL Test Point FLT850 Video of Roll back showing IGV Ice Accretion



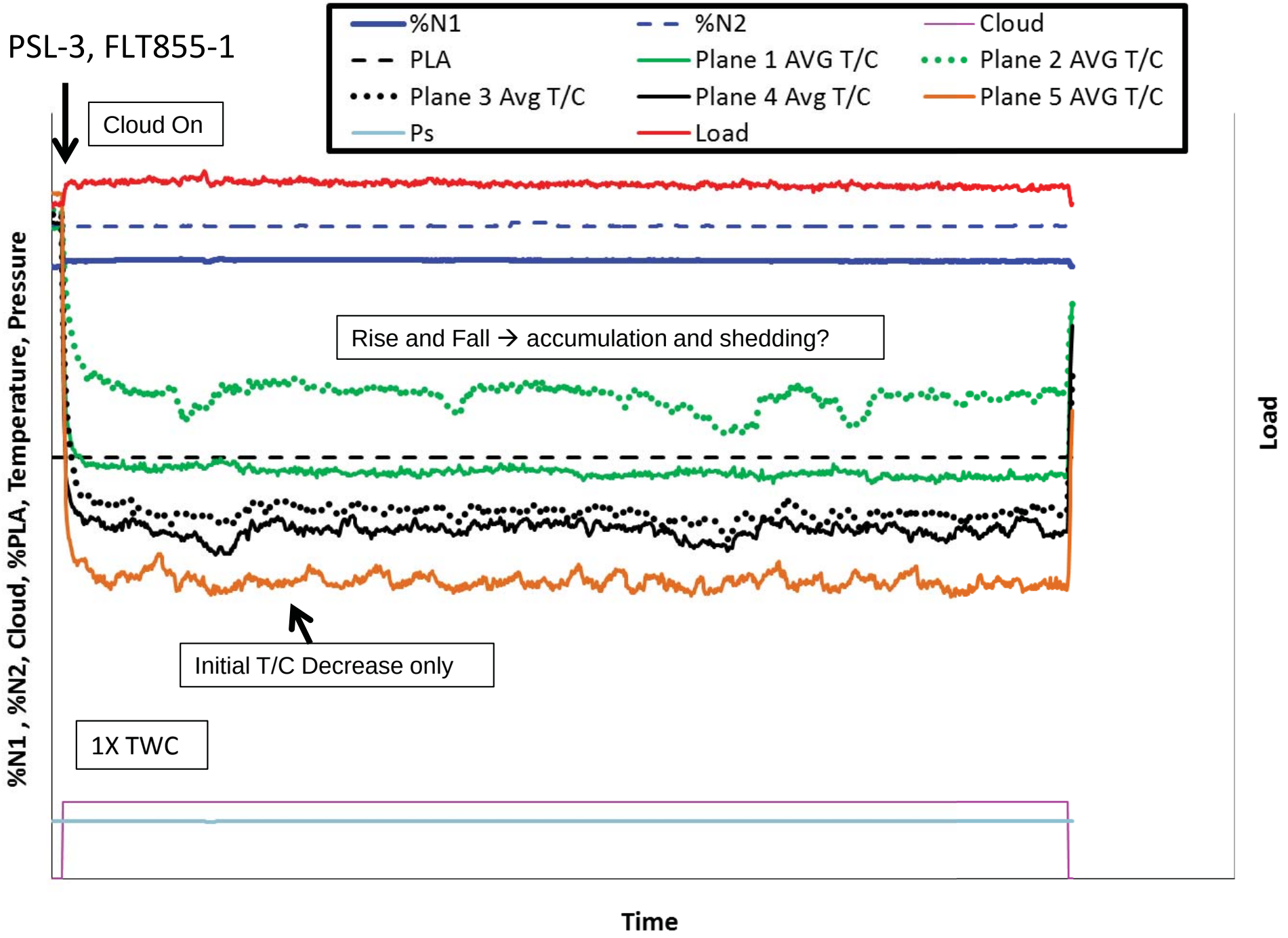
Plane 4 Thermocouple traces showing Flight Test (top) vs PSL Test (bottom)



Rollback Indicators Chart- roll back test point



Rollback Indicators Chart --- no rollback test point

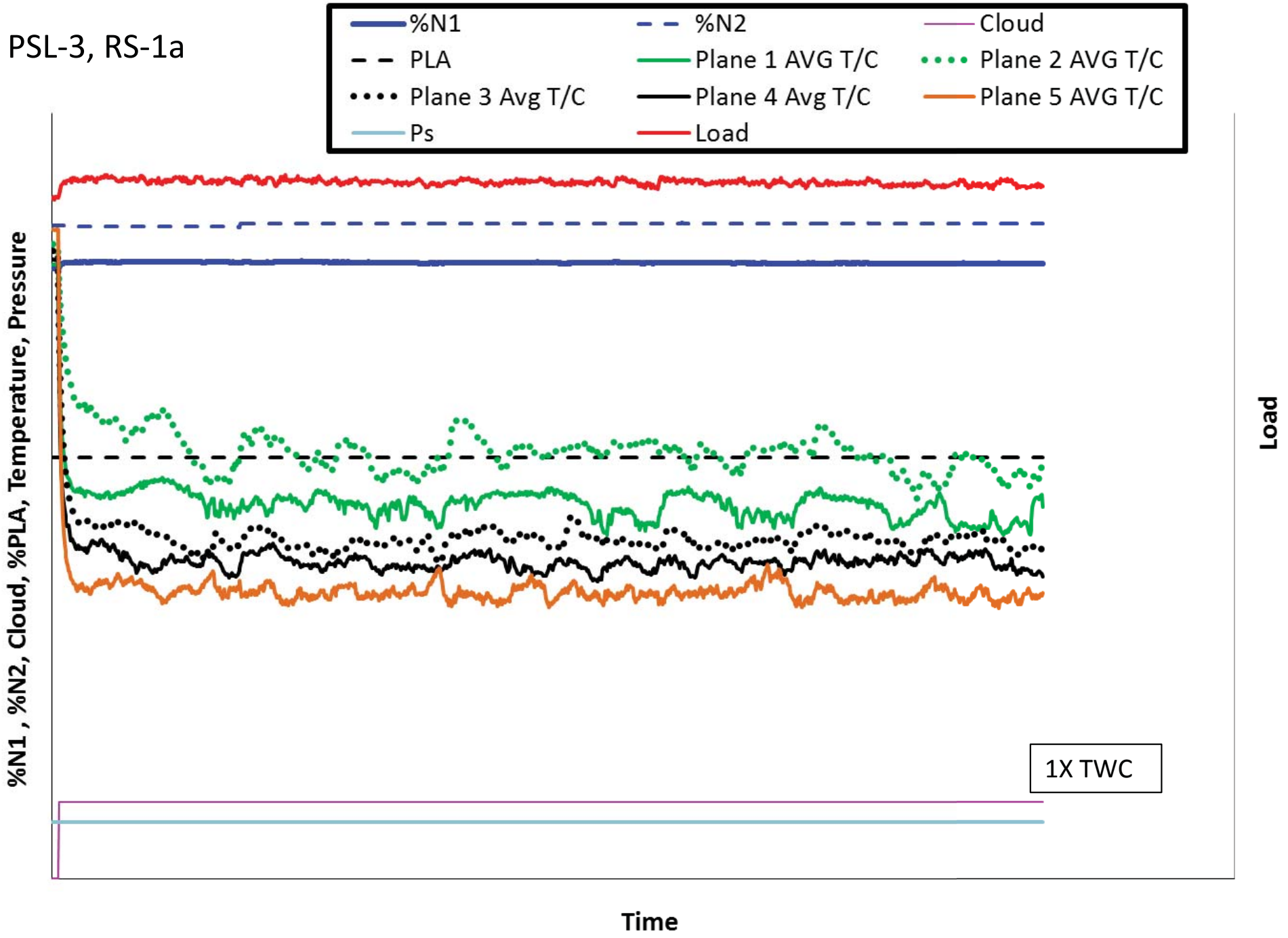


Secondary Objective: Achieved Successfully
Reproduced selected revenue service field events

1. Successfully turned on and off a roll back point

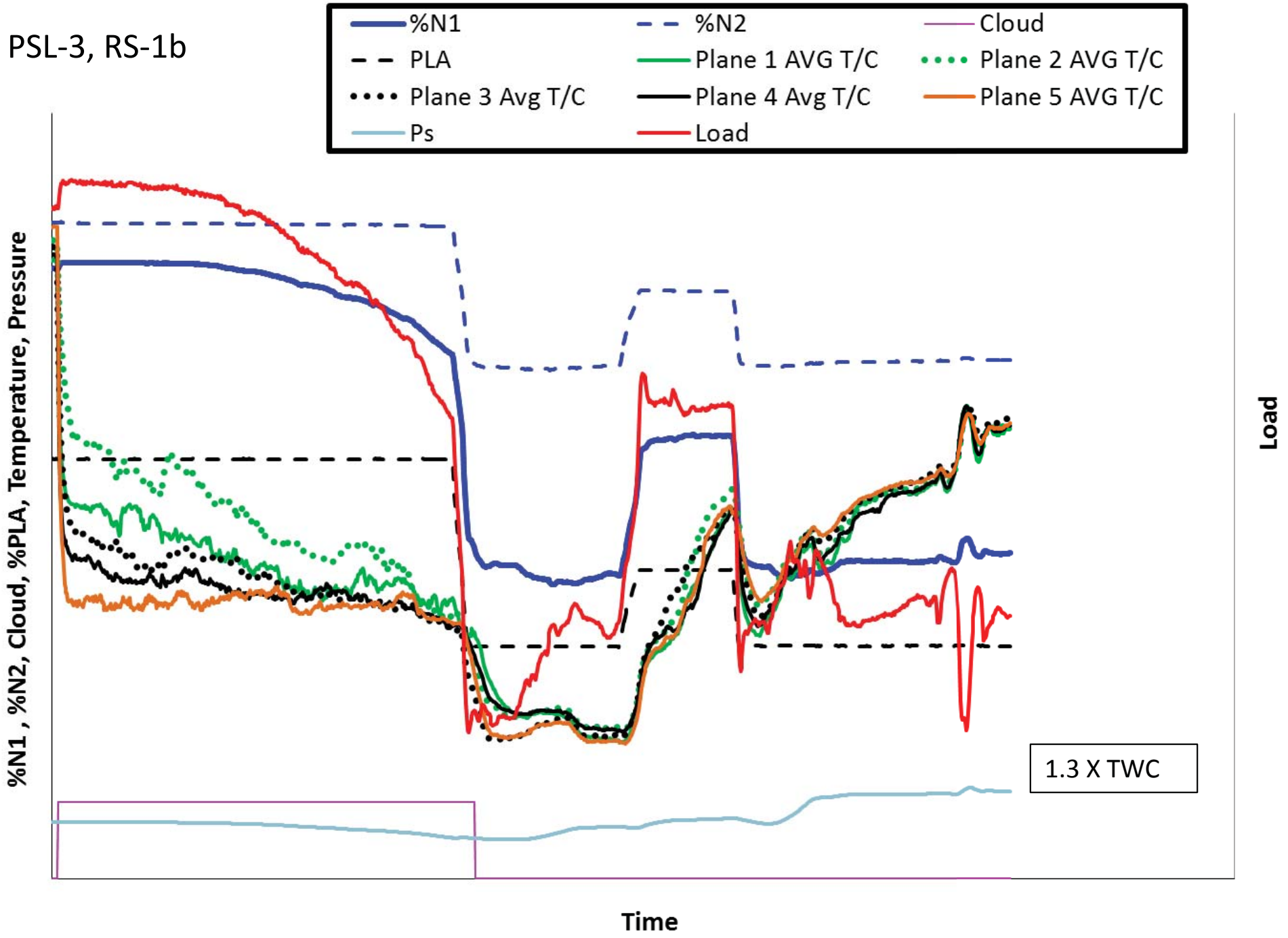
Revenue Service Test Point— no Roll back

PSL-3, RS-1a



Revenue Service Test Point – Roll Back

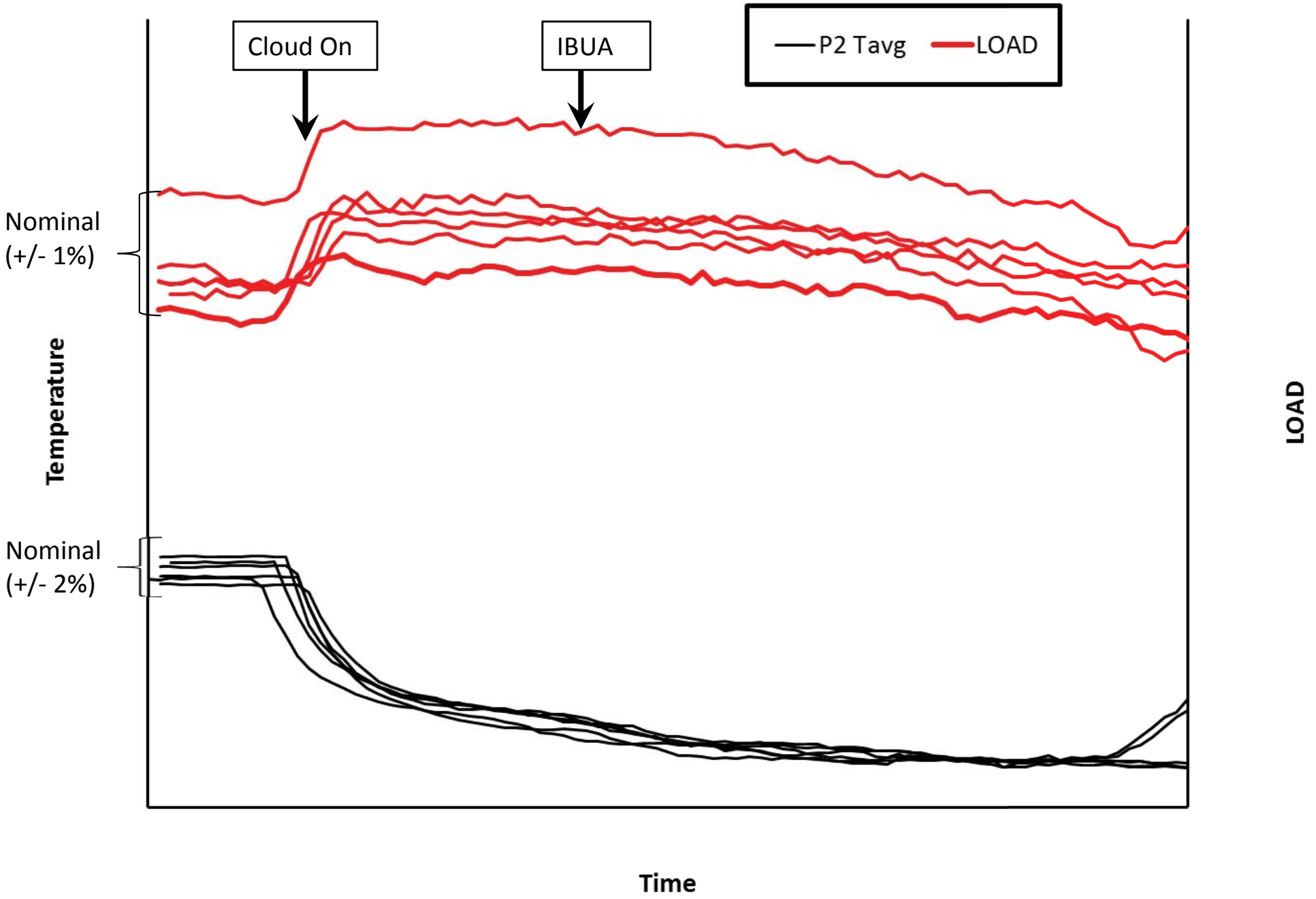
PSL-3, RS-1b



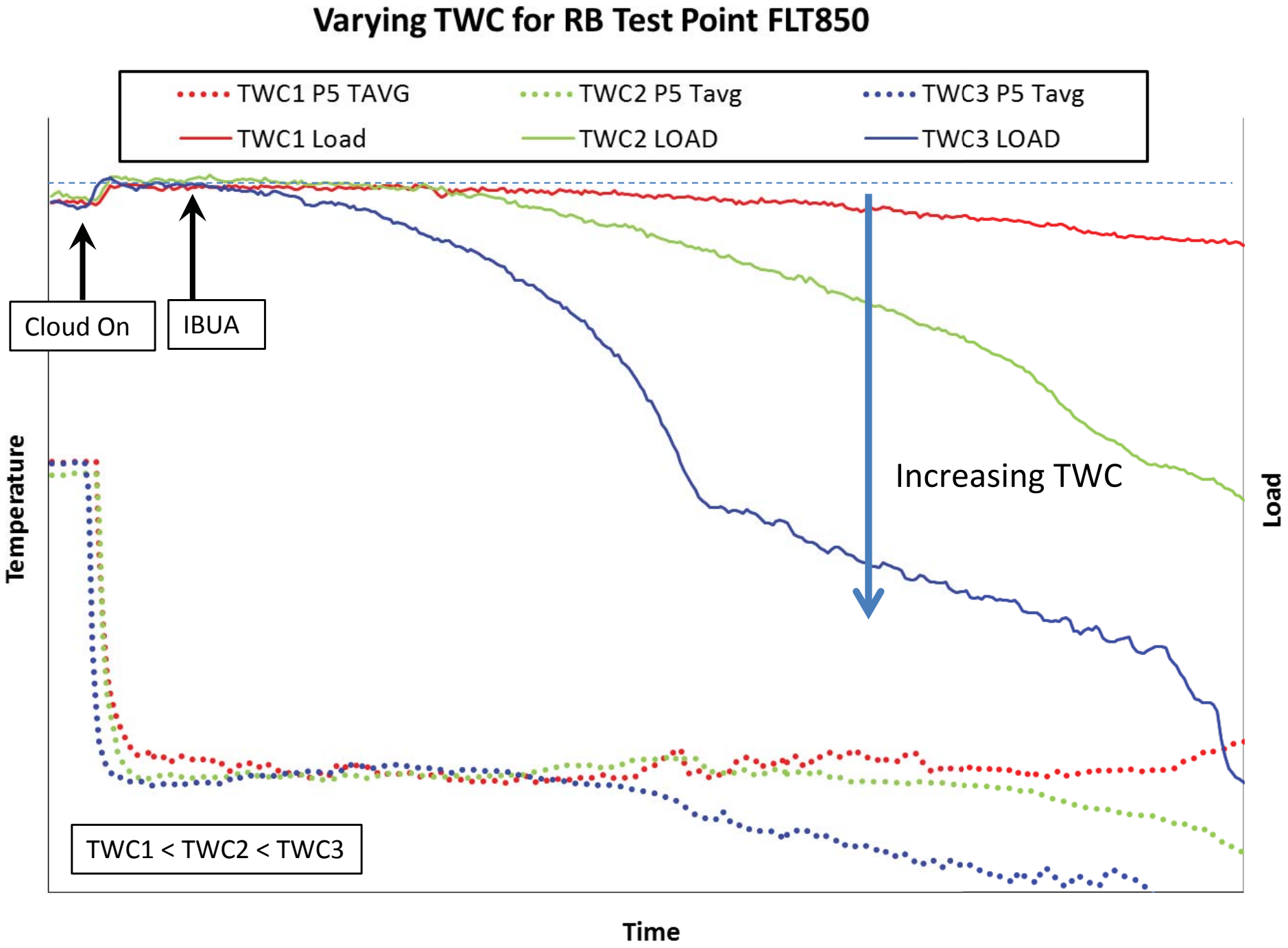
Additional Objectives: Achieved Successfully

1. Demonstrated repeatability of PSL
2. Generated Engine data for selected facility and engine operational parameters
    1. Facility: Cloud Total Water Content (TWC)
    2. Facility: Cloud Mean Volumetric Diameter (MVD)
    3. Facility: Low Altitude Test Point
    4. Engine: Anti-Ice System

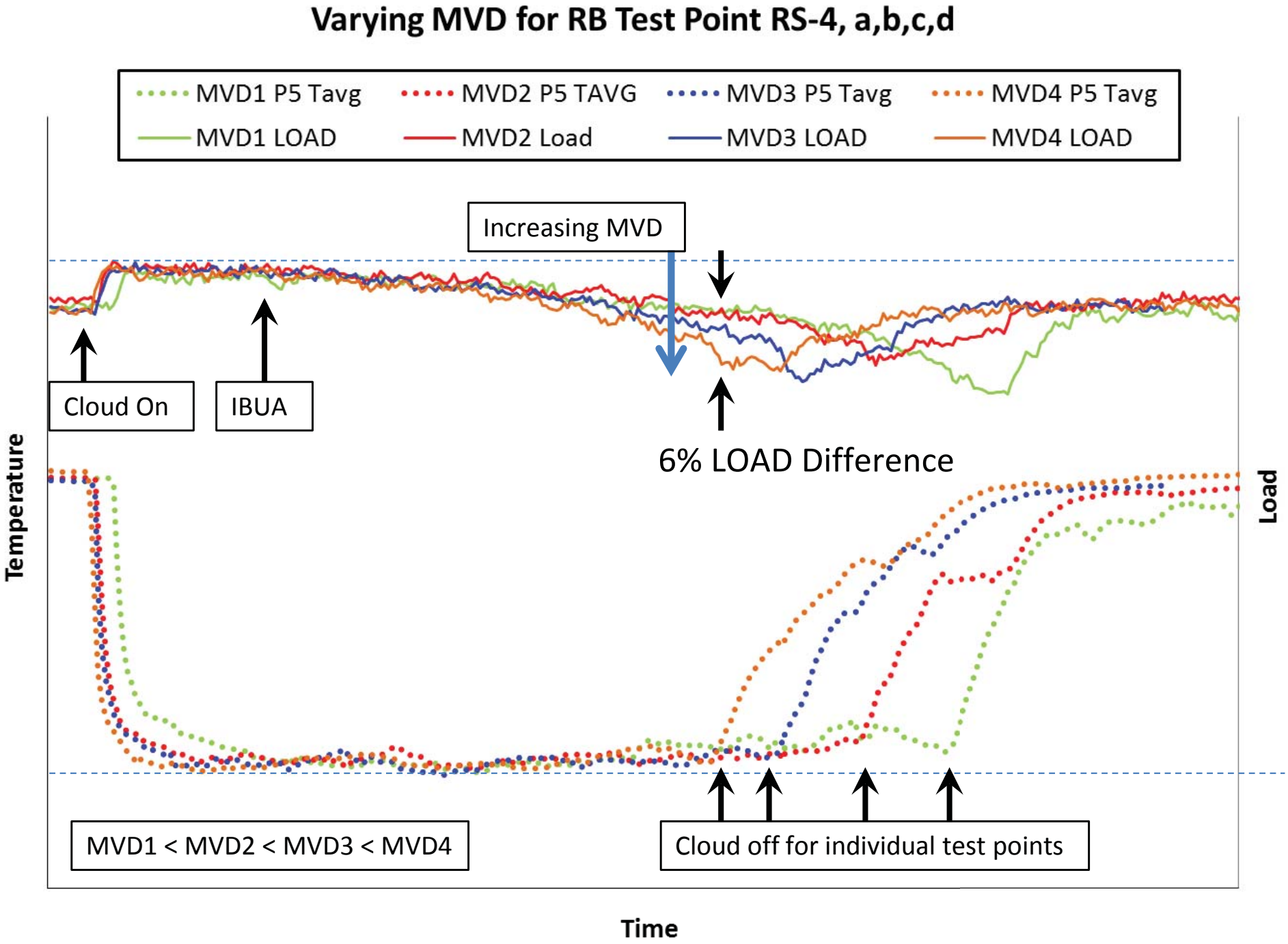
Repeated Test Point



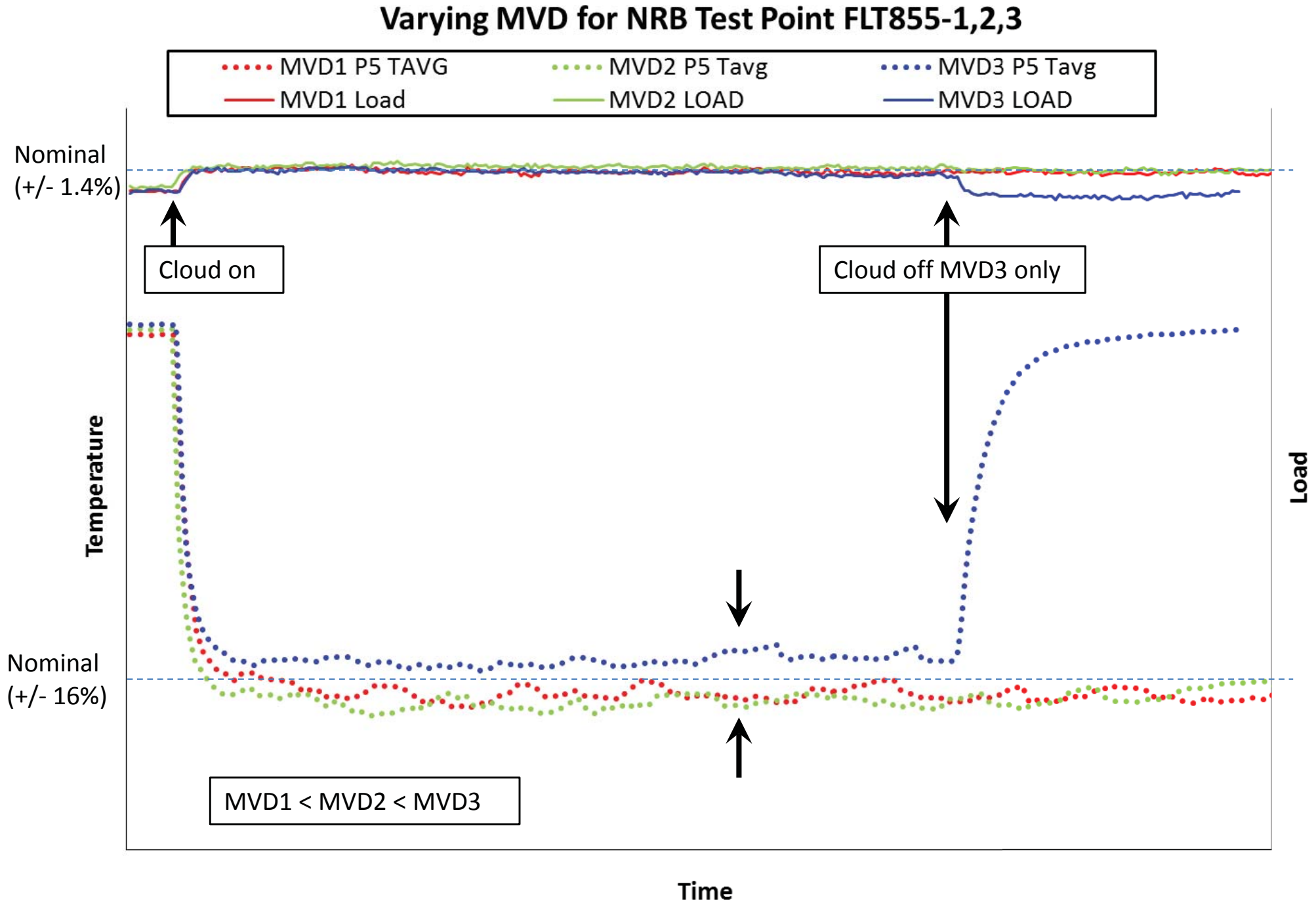
Total Water Content – Strong influence on rollback/rate of ice build up



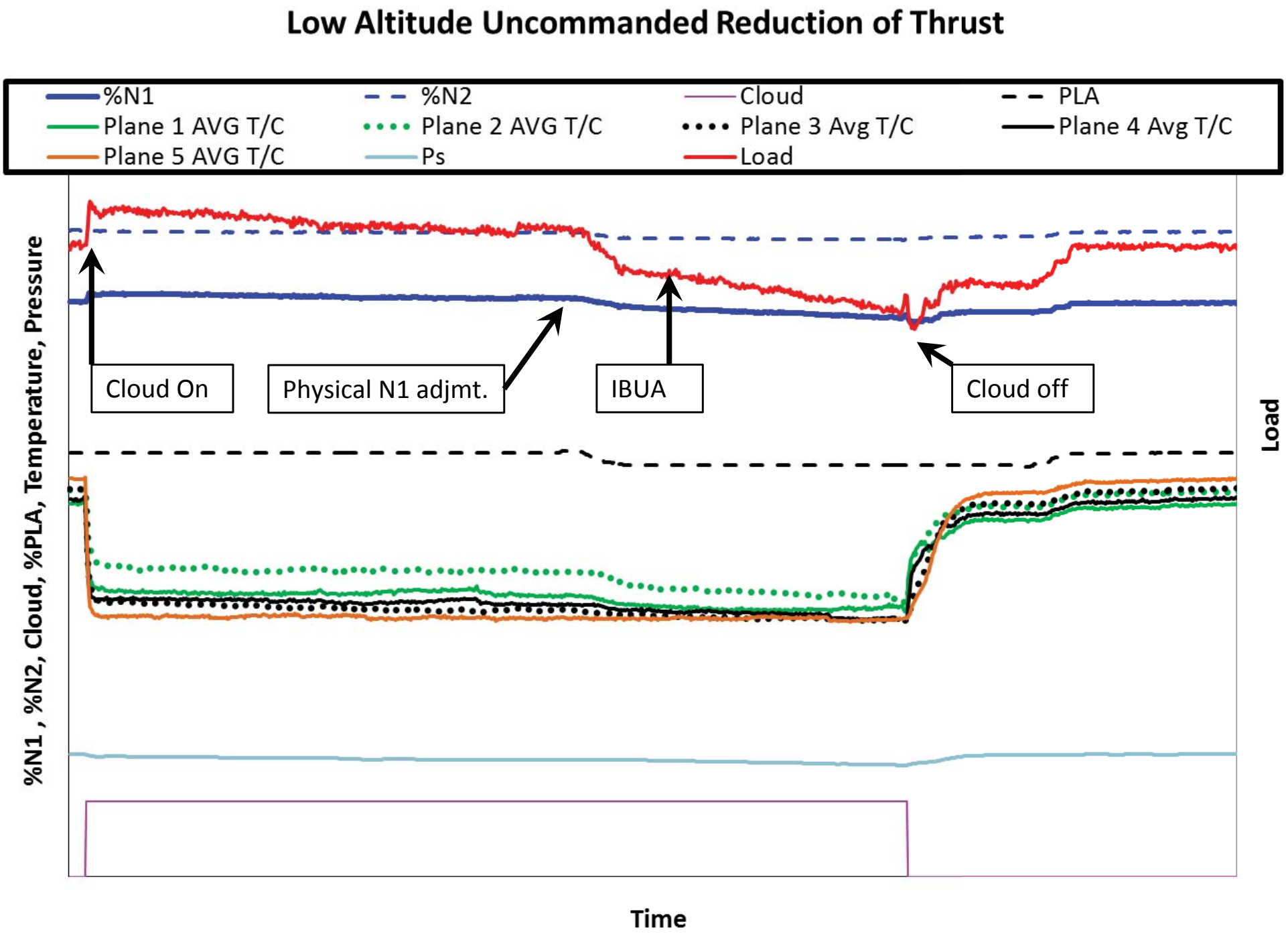
Mean Volumetric Diameter Weak effect on rate not onset of ice build-up



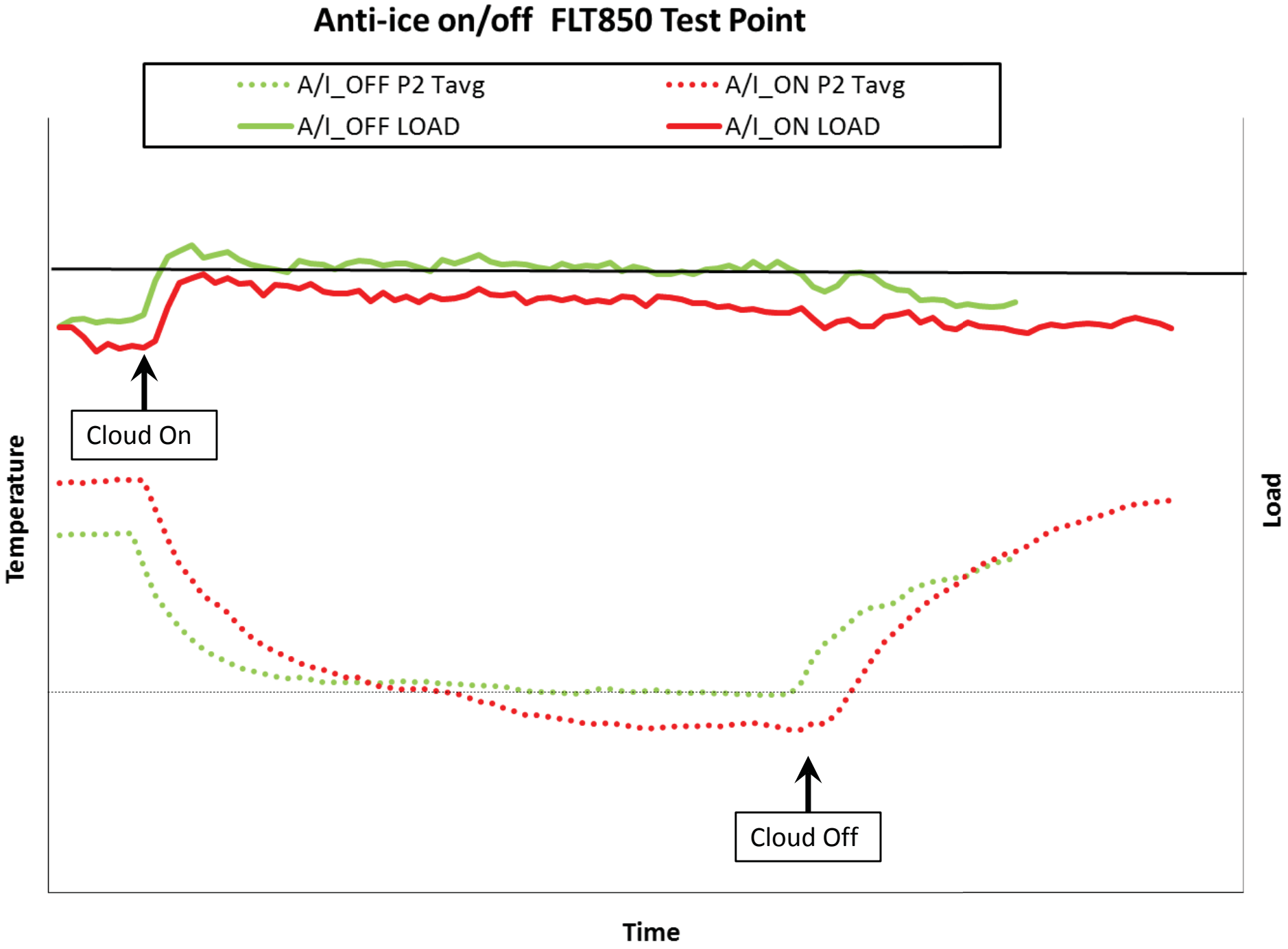
Mean Volumetric Diameter no effect on onset of ice build-up



Low Altitude Test Point



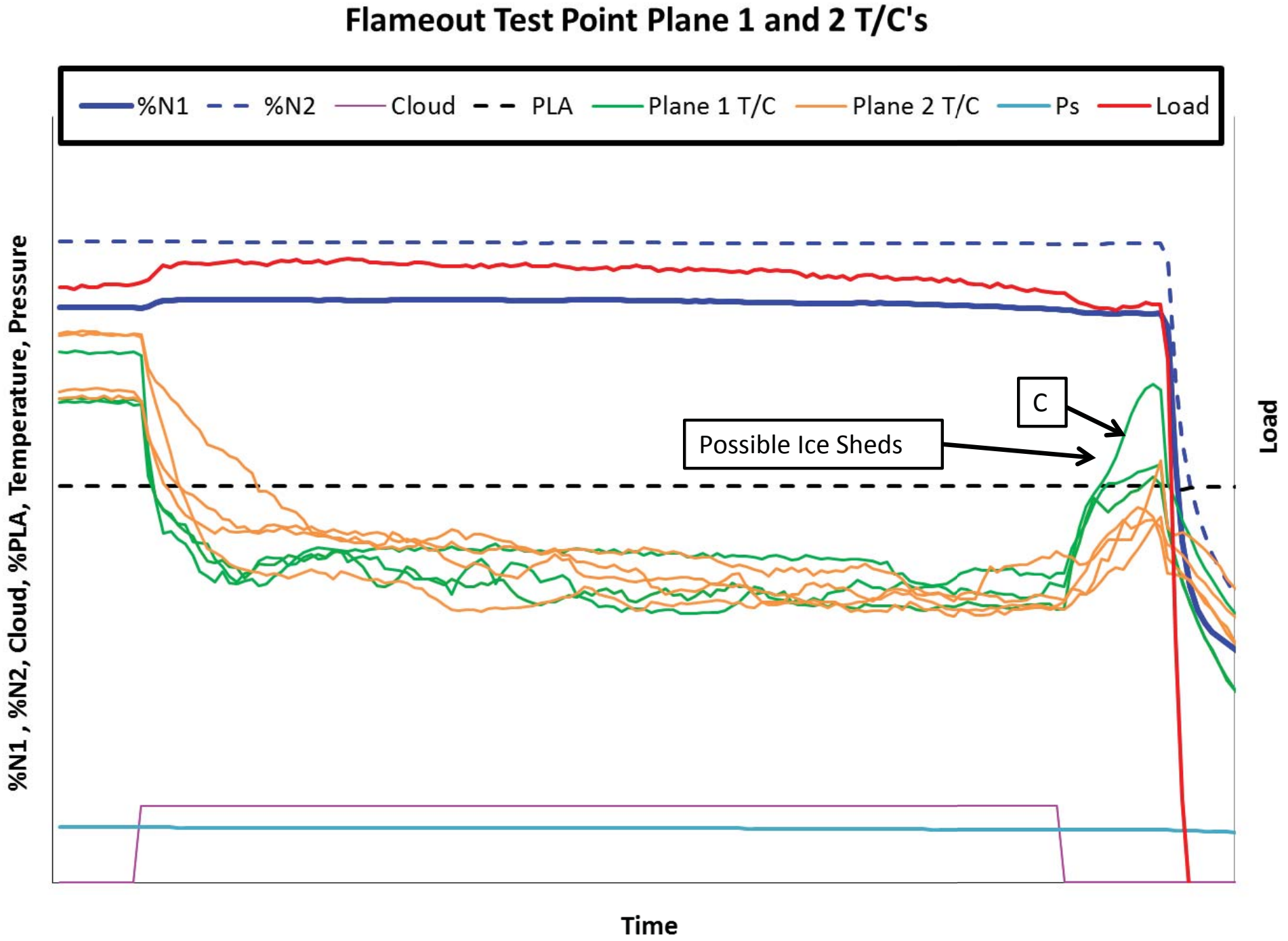
Anti-ice System Influences onset of ice build up



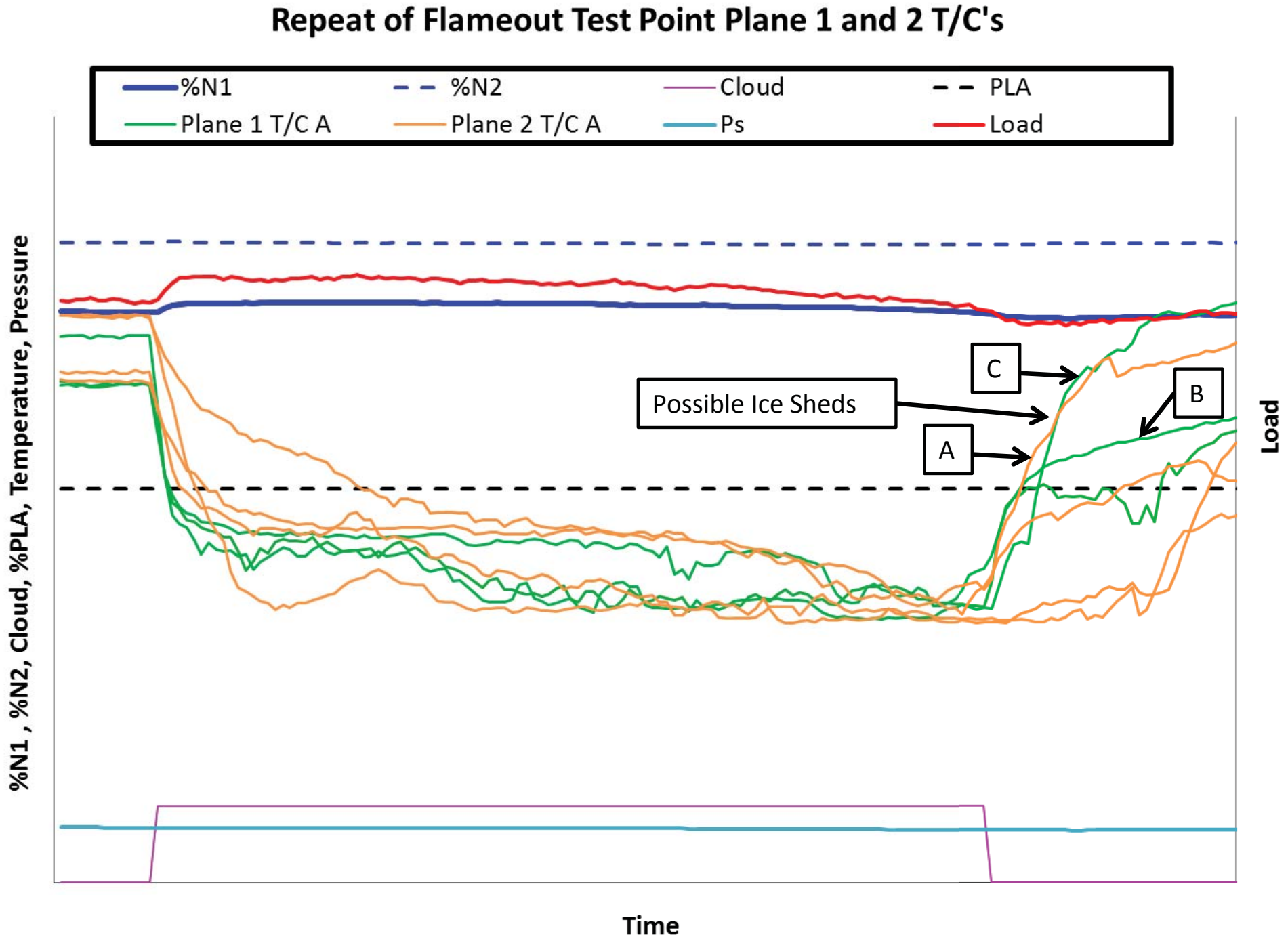
Additional Test Observations

1. Flameout Test Point
2. Possible Surge Test Point
3. Mineral Deposits Flow Path Hardware
4. Hardware Damage
5. Heated spinner liquid water layer
6. Ice buildup aft of heat probes in tunnel flow path

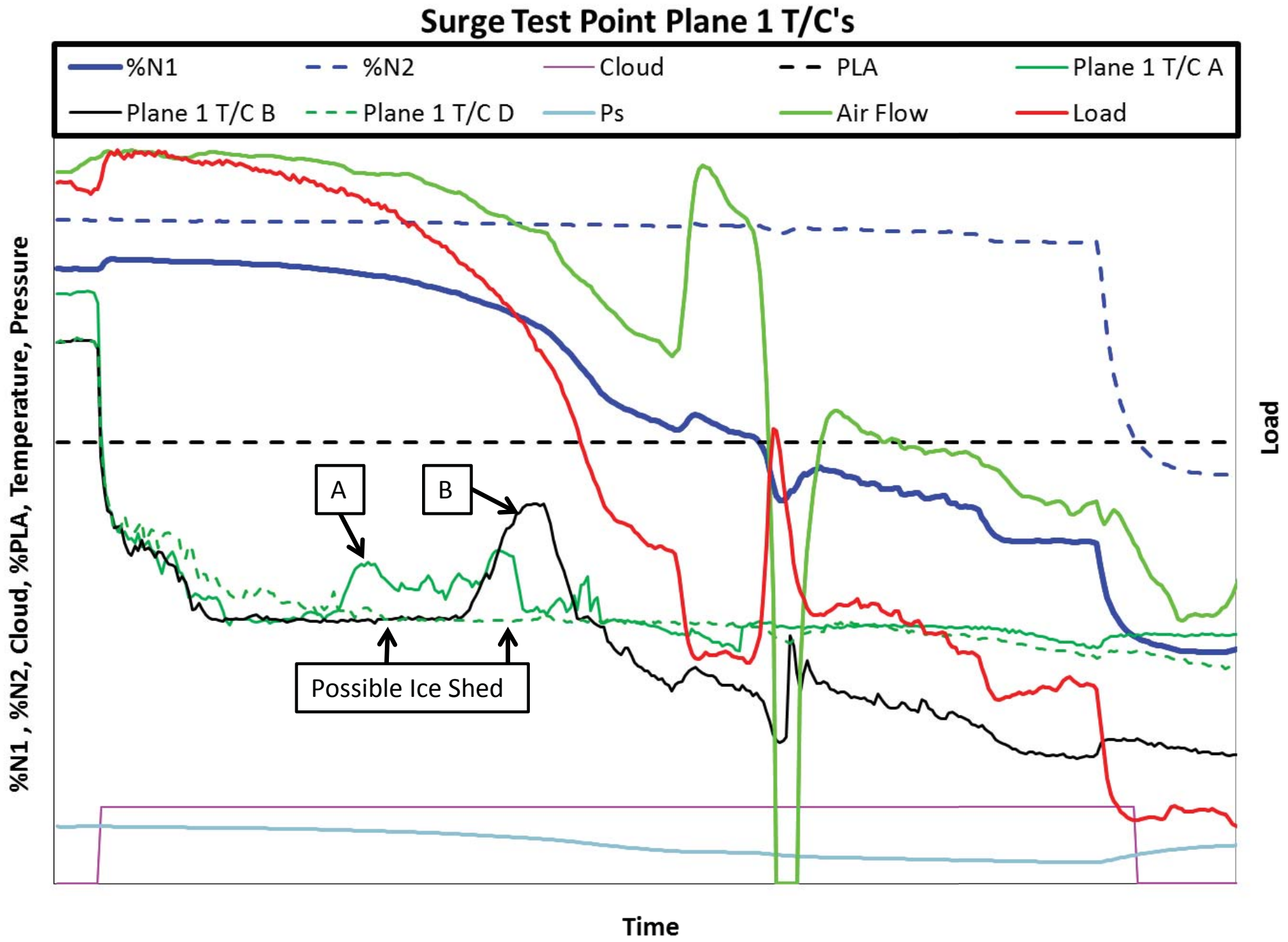
Flameout Test Point – Individual Plane 1 & 2 T/C's Shown



Repeat Flameout Test Point–Individual Plane 1&2 T/C's Shown



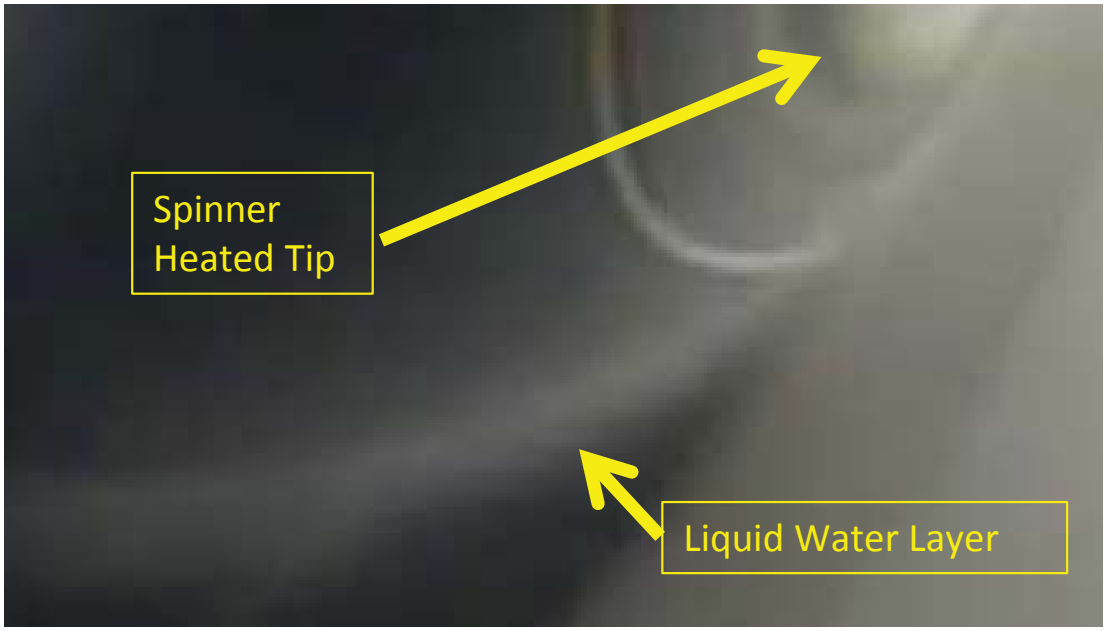
Surge Test Point – Individual Plane 1 T/C's Shown



Mineral Deposits on flow path hardware

Hardware damage that occurred during a full roll back PSL test point

Liquid Water Layer off of heated spinner

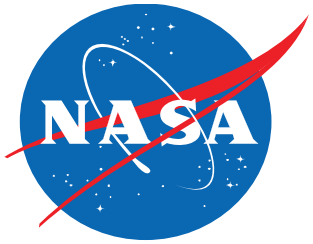


Ice forms aft of heated probes in the flow path

Summary

- Validated a New Facility R&D Capability
  - Successfully calibrated / duplicated known flight test events
  - Successfully recreated known revenue service field events
  - Demonstrated repeatability
- Strong correlation demonstrated: Cloud TWC and rate of ice buildup/rollback
  - Demonstrated ability to turn on/off ice buildup / rollback by adjusting TWC
- Weak correlation demonstrated: Cloud MVD and rate of ice buildup/rollback
  - No affect on the onset of ice build up
- Rollback indicator chart developed → initial reduction of thrust occurs prior to N1 reduction due to restricted core air flow
- Engine anti-ice system required to be on for roll back to occur
- Demonstrated ability to build up ice at low altitudes using NASA tools to predict tunnel ambient temperature

PSL-3 Engine Icing Validation Test Team


NASA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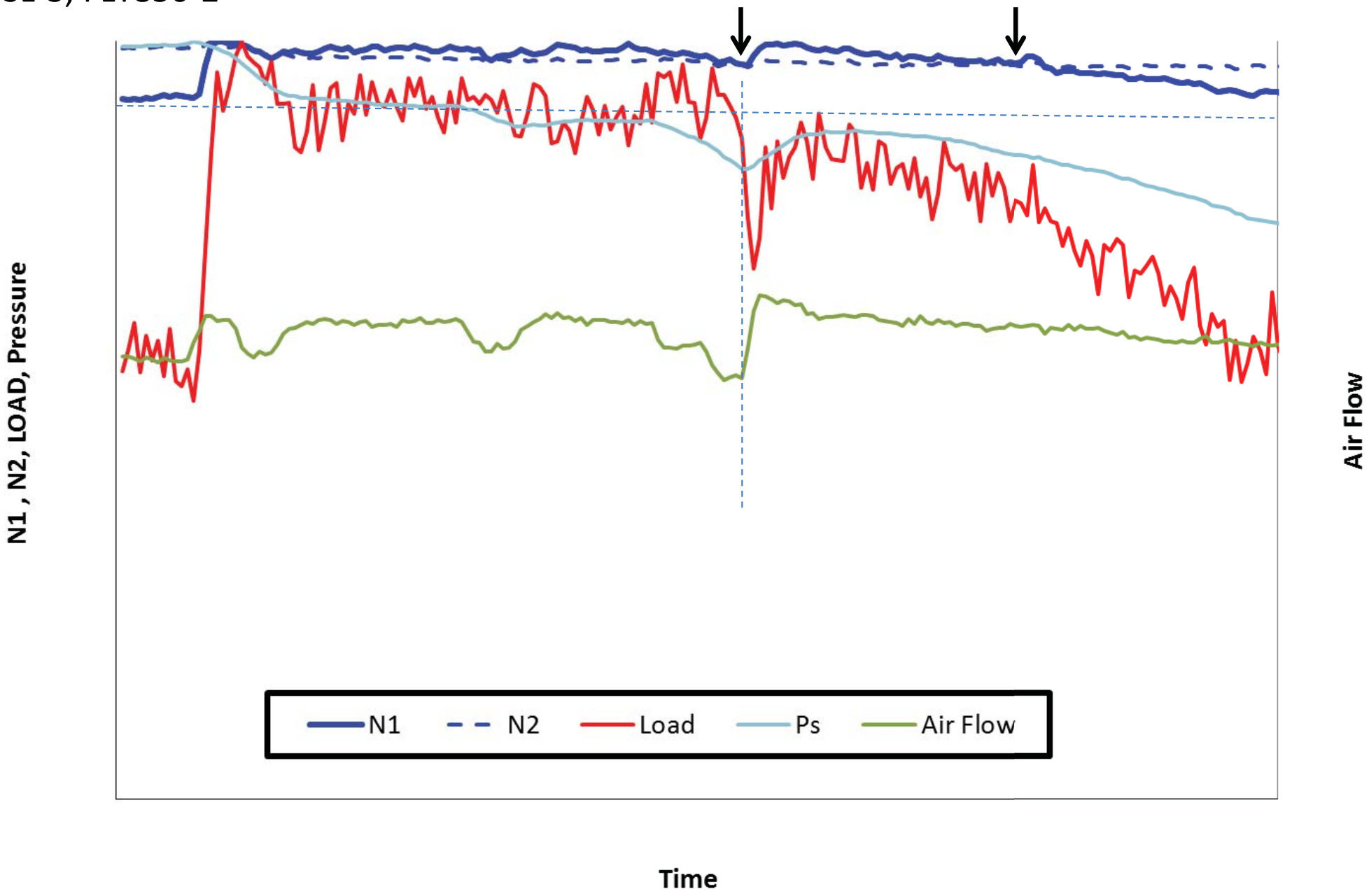
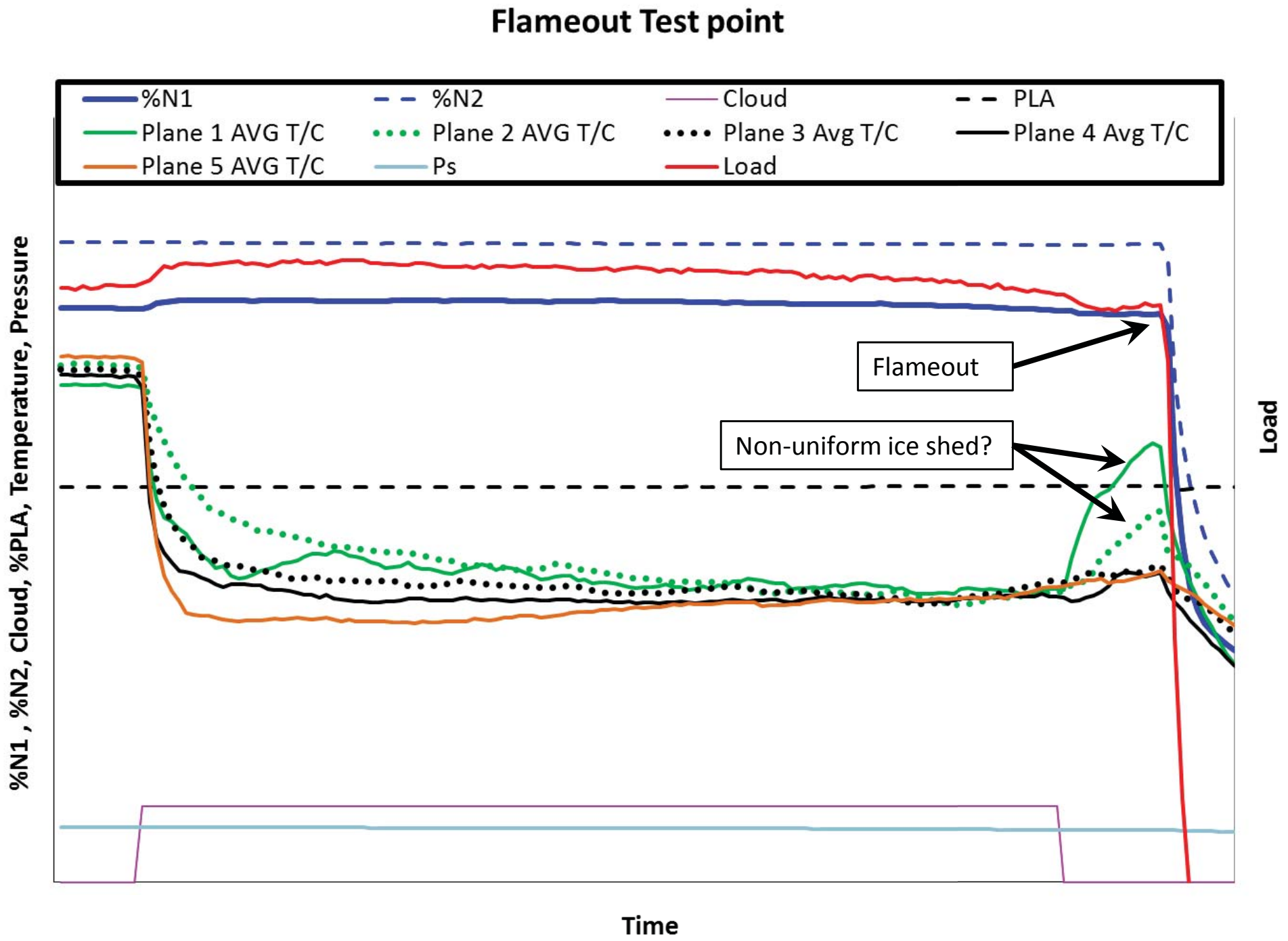
Back-up Slides

Loss of Thrust begins in Core Flow Path – not from N1 reduction

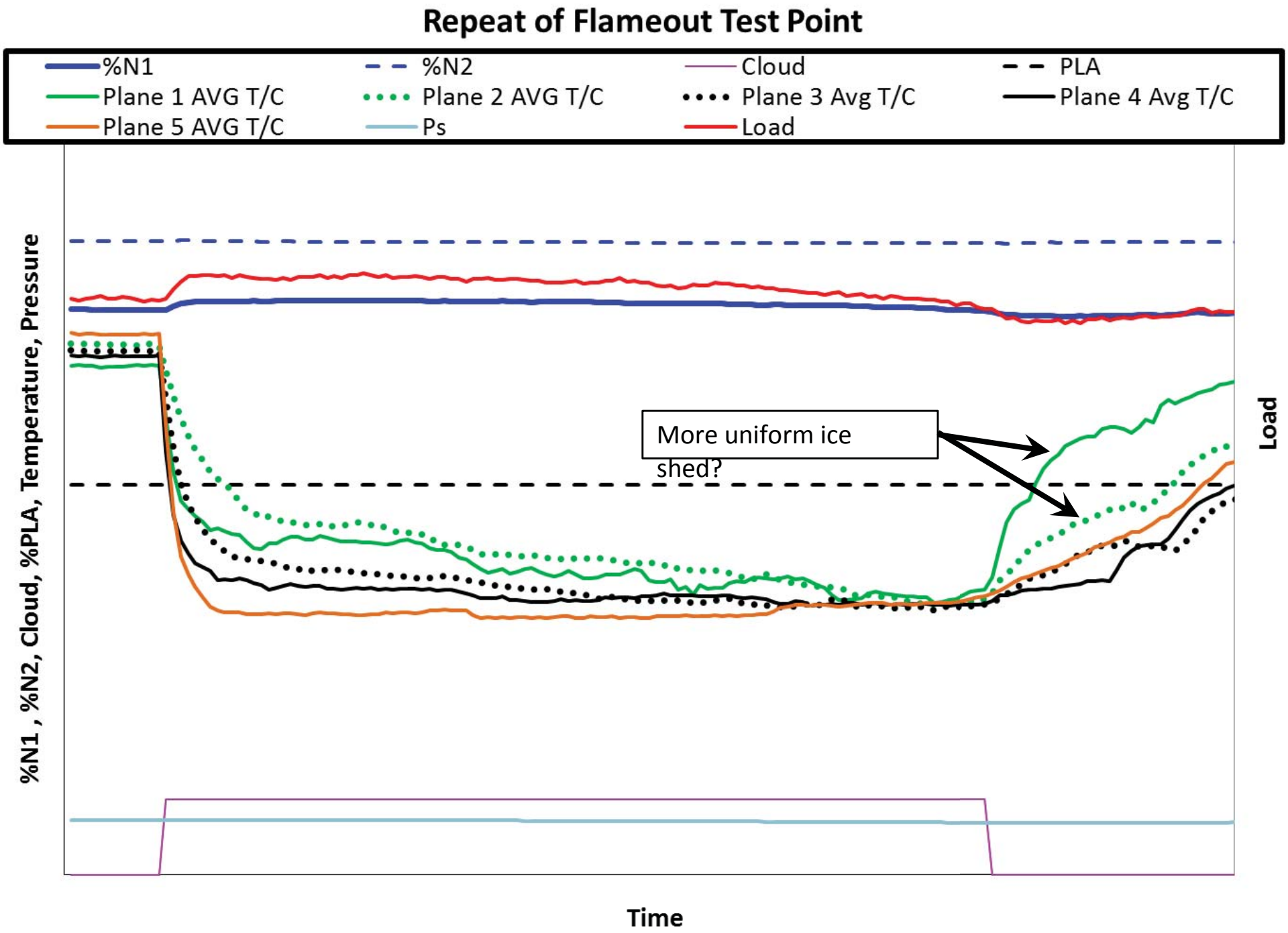
PSL-3, FLT850-2



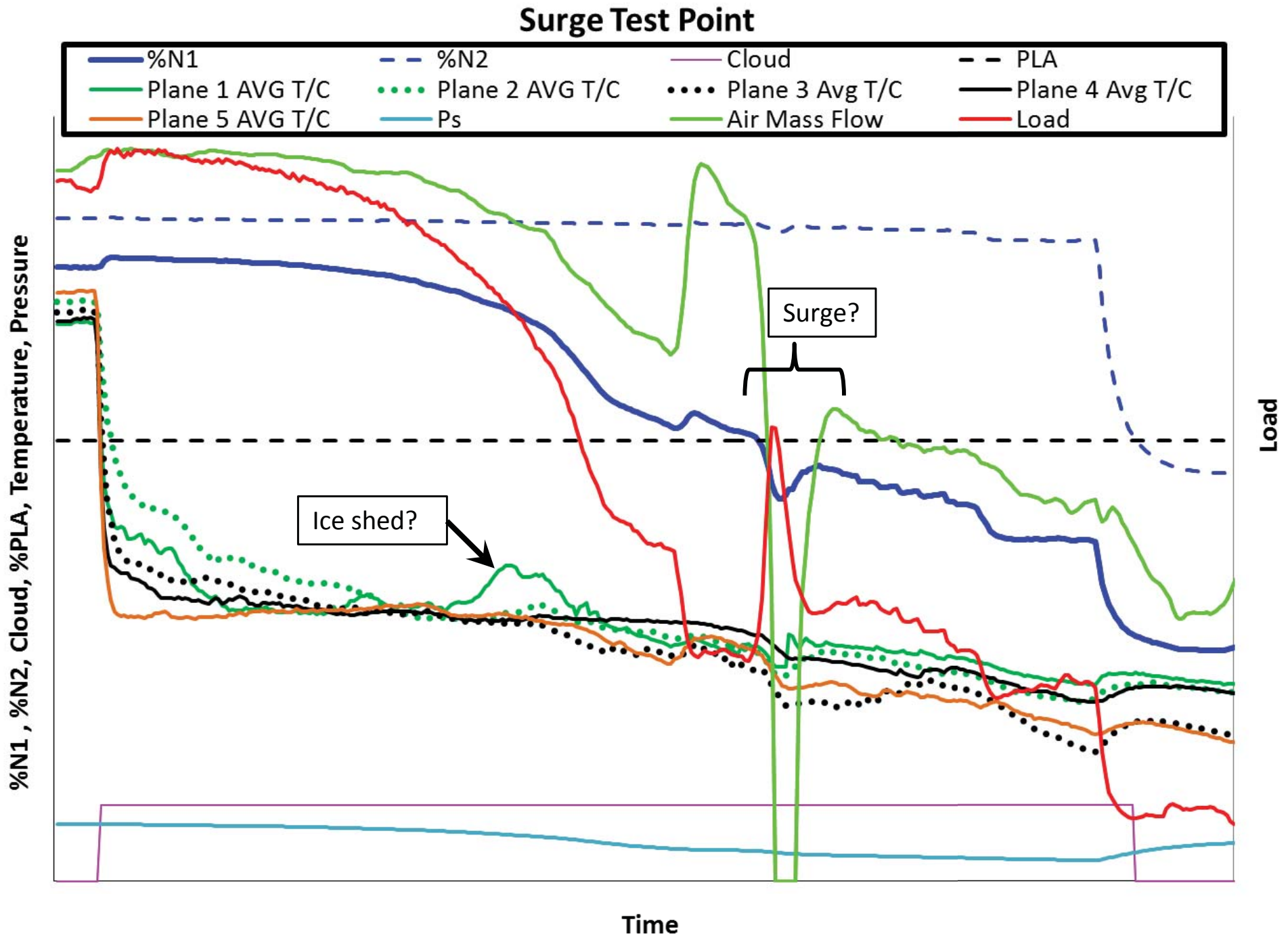
Flameout Test Point – Average Plane T/C's Shown



Repeat Flameout Test Point – Average Plane T/C's Shown



Surge Test Point – Average Plane T/C's Shown



Reverse flow rivulet