NASA nvPM Test

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PMTG MEASURE ahg call
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Overview

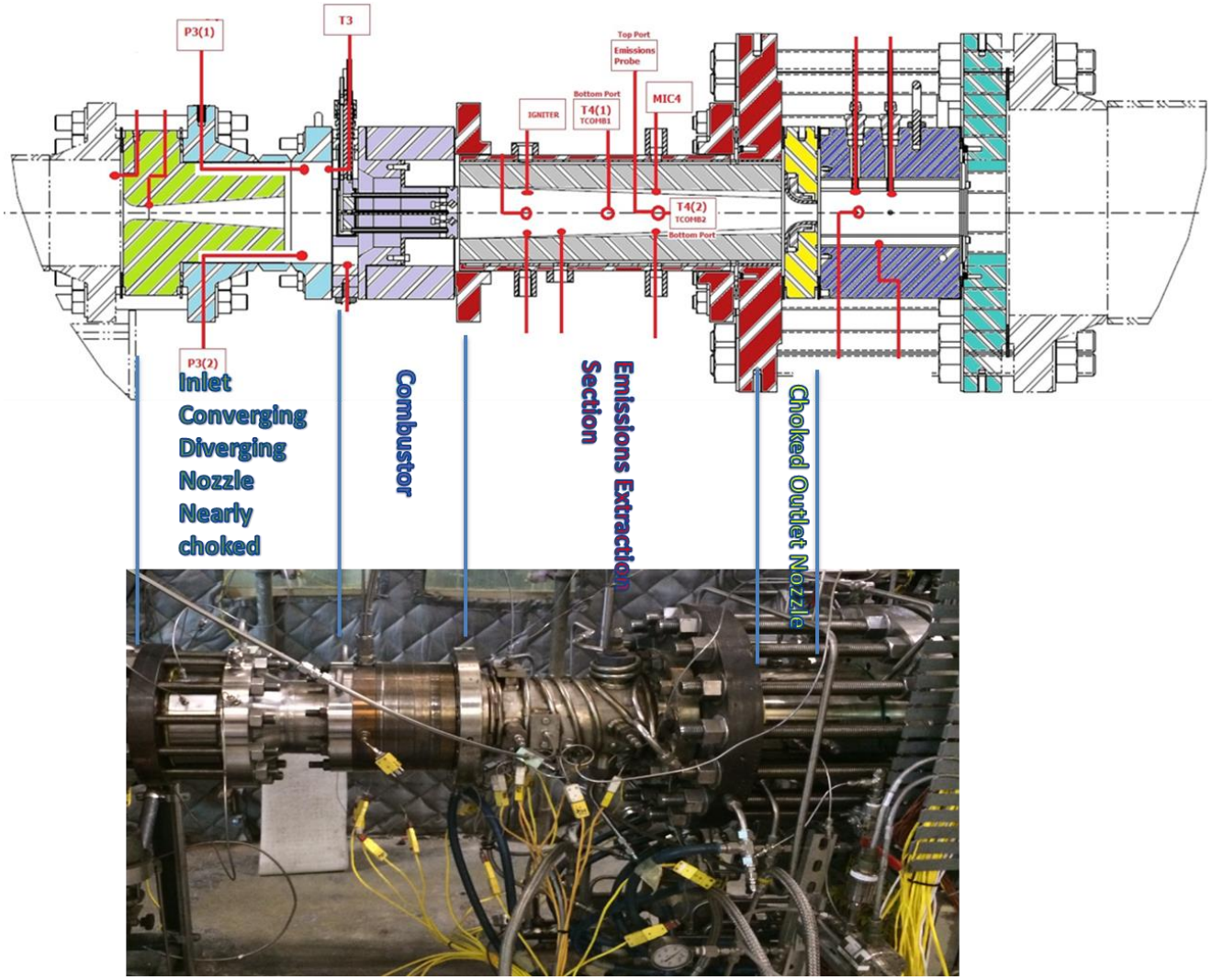
- Test period: 19-27 October 2016
- Location: NASA Glenn Research Center, Cleveland, OH
- Emissions Source: NASA 9 point Lean Direct Injection (LDI) combustor
- Test Matrix:
  - Measurements were made at a combination of T3 and P3 settings for various FAR values
    - Data acquired for 39 test points over 3 days of testing
  - Gaseous emissions
    - Undiluted: [NO_x, NO, CO, UHC, CO_2] were measured by NASA
    - Diluted: [CO_2] were measured by NASA and MST on their respective systems
  - PM emissions (number, mass, size, composition) were measured using the NASA system and North American Mobile Reference System
- Fuel samples were collected

Objectives

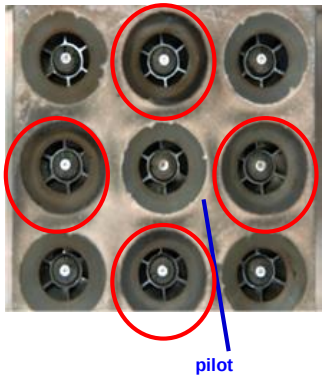
- Investigate the influence pressure and temperature variations on nvPM emissions

- Compare nvPM emissions measured using NASA system with North American Mobile Reference System

NASA 9 point Lean Direct Injection (LDI) combustor



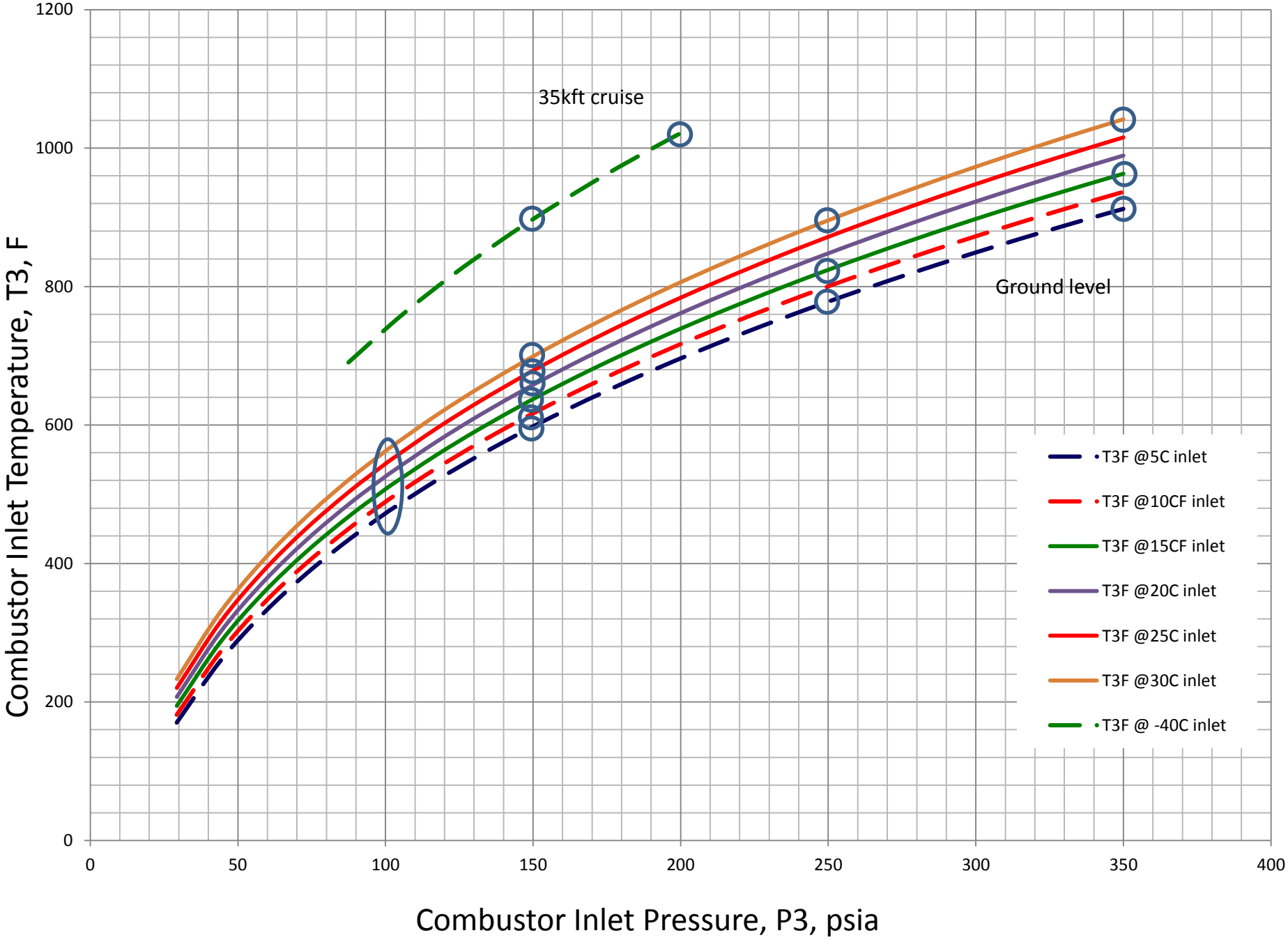
Test Hardware: 9 point LDI



Woodward Simplex fuel nozzles
9 injection points (60^{o} air swirlers and fuel nozzle)

Pilot = 1 injection point
Main 1 = 4 injection points
Main 2 = 4 injection points

FN_{US} = 2.9 for 9-pt LDI
ACd = 1.3 in^2


1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
Combustor Inlet Temperature, T3, F
Combustor Inlet Pressure, P3, psia
35kft cruise
Ground level
T3F @5C inlet
T3F @10CF inlet
T3F @15CF inlet
T3F @20C inlet
T3F @25C inlet
T3F @30C inlet
T3F @ -40C inlet

Instruments

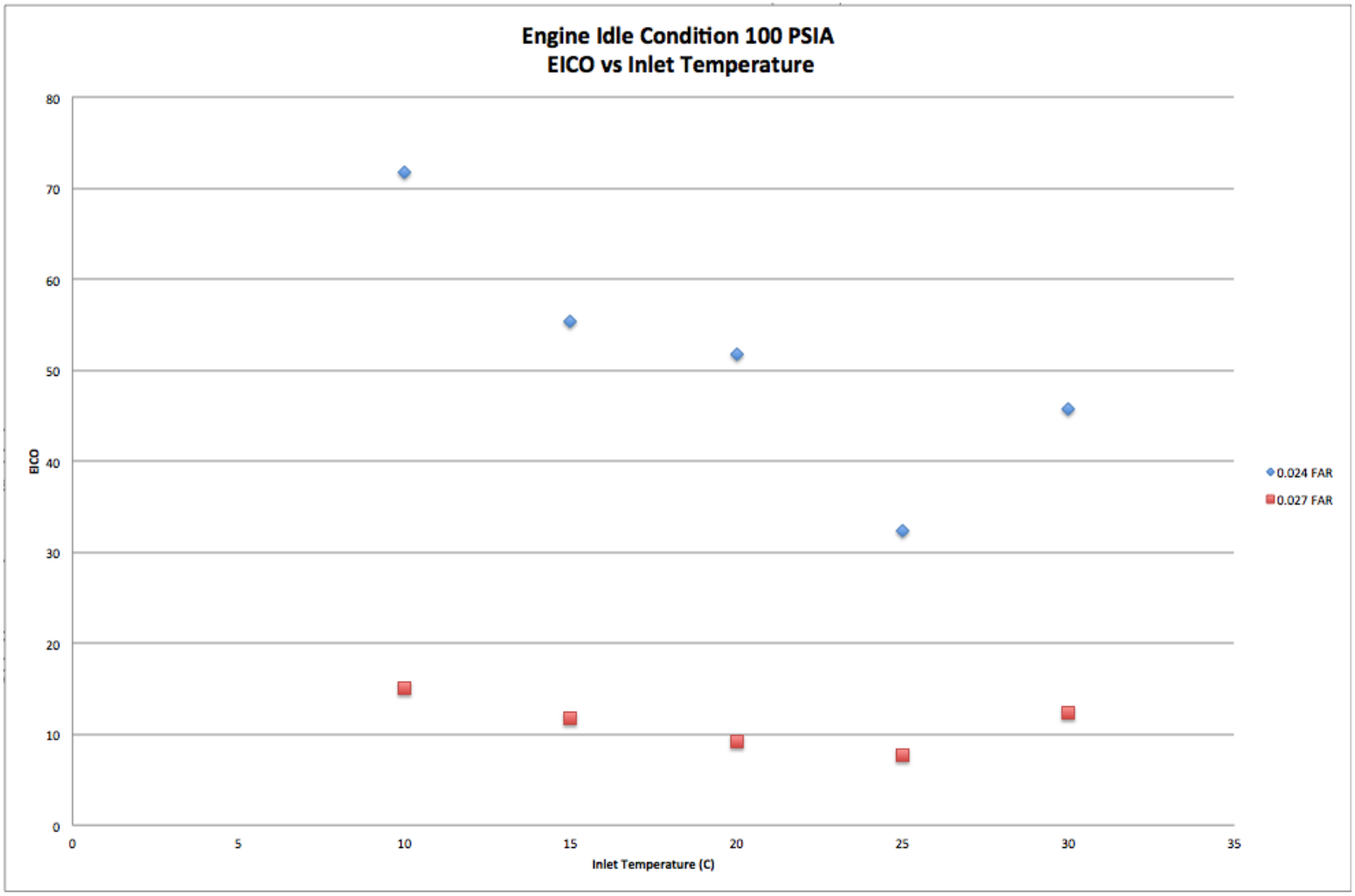
NASA System

- Number:
  - 3775 CPC (with thermal denuder)
  - 3775 CPC
- Mass:
  - AVL MSS Plus
  - ARI CAPS-PM_{ex}
- Size:
  - TSI SMPS
  - TSI EEPS

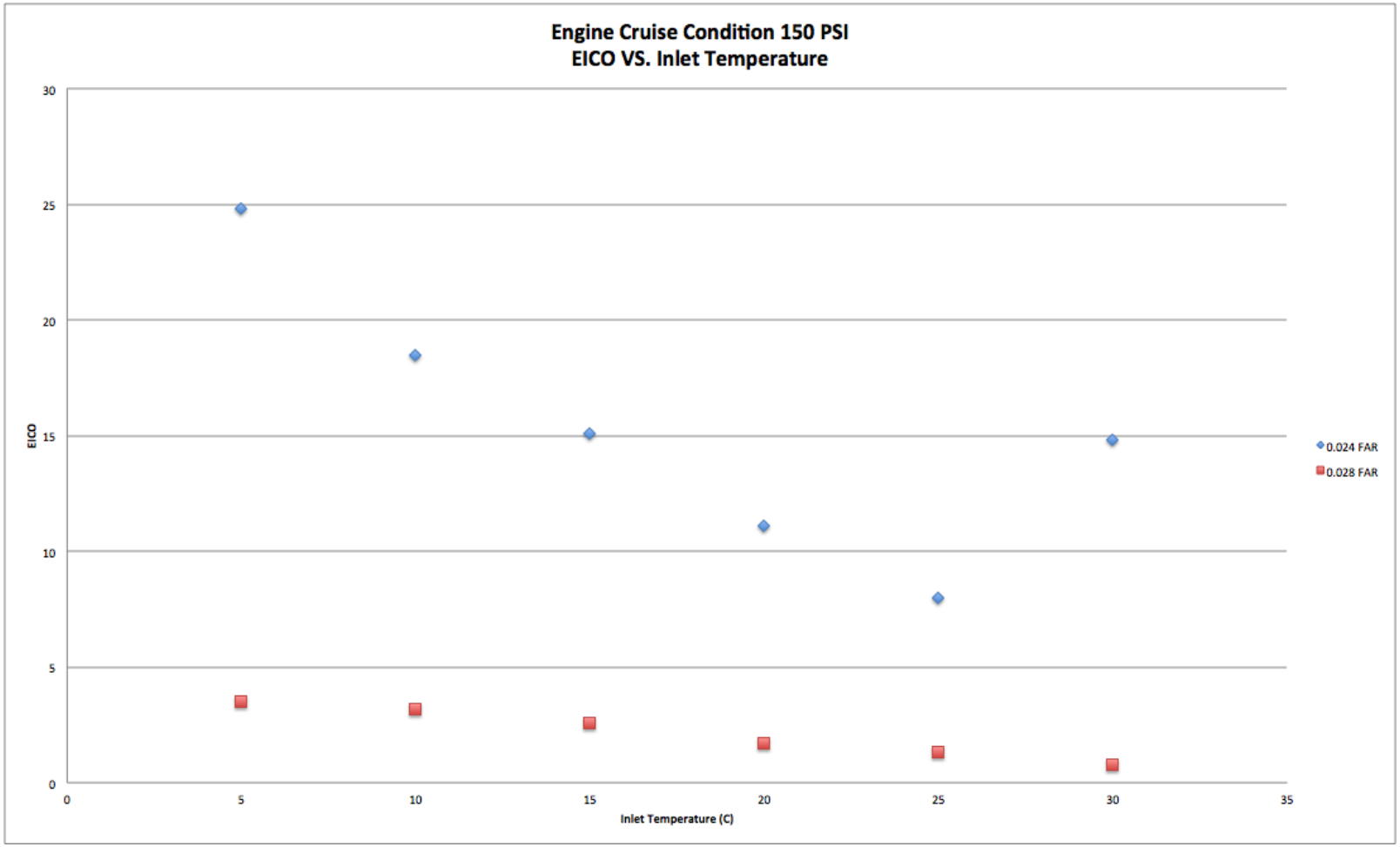
North American Mobile Reference System

- Number:
  - AVL APC (with catalytic stripper)
- Mass:
  - AVL MSS
  - ARI CAPS-PM_{ex}
  - Artium LII-300 (not available for test)
- Size:
  - Cambustion DMS500
- Composition
  - ARI CToF-AMS

Gaseous Emissions Idle



Gaseous Emissions Cruise

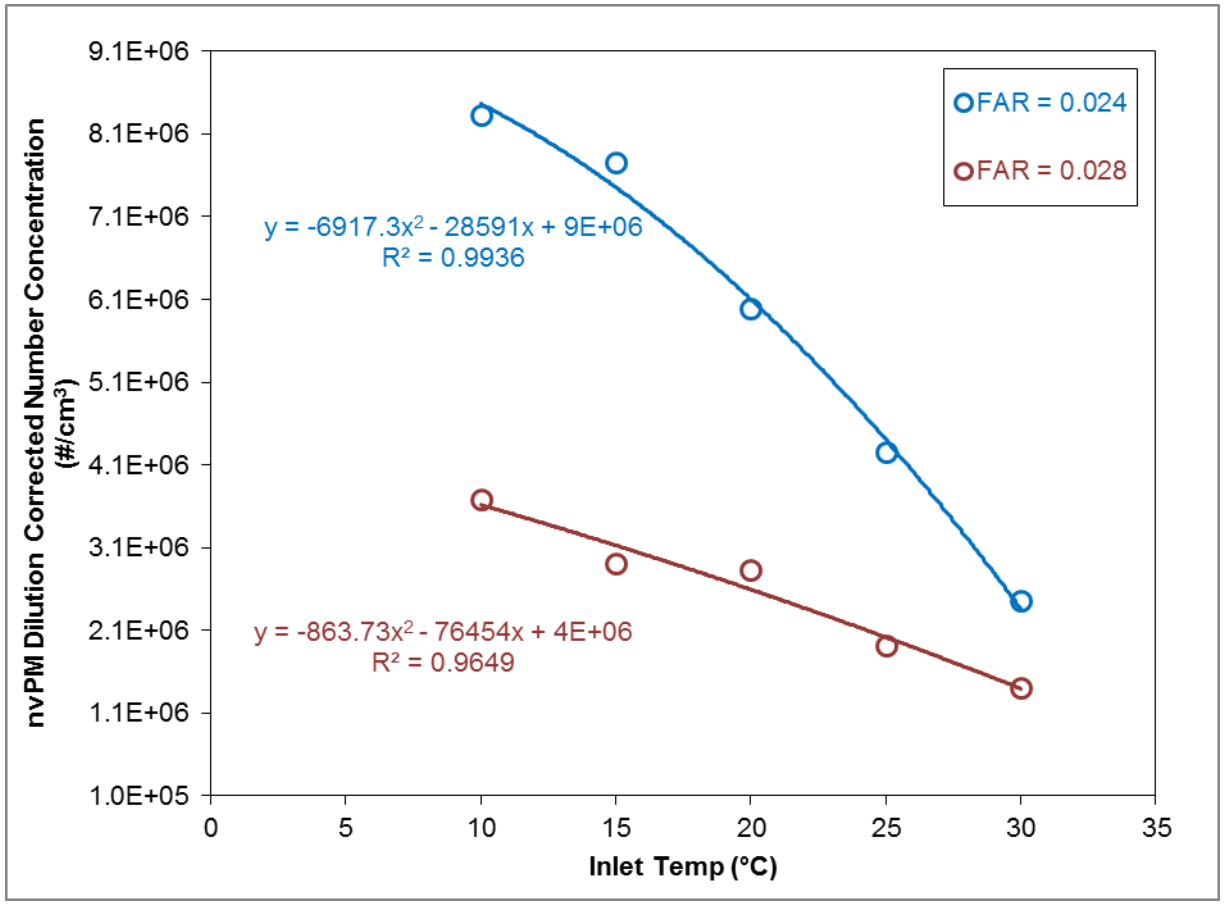


Preliminary nvPM data Analysis

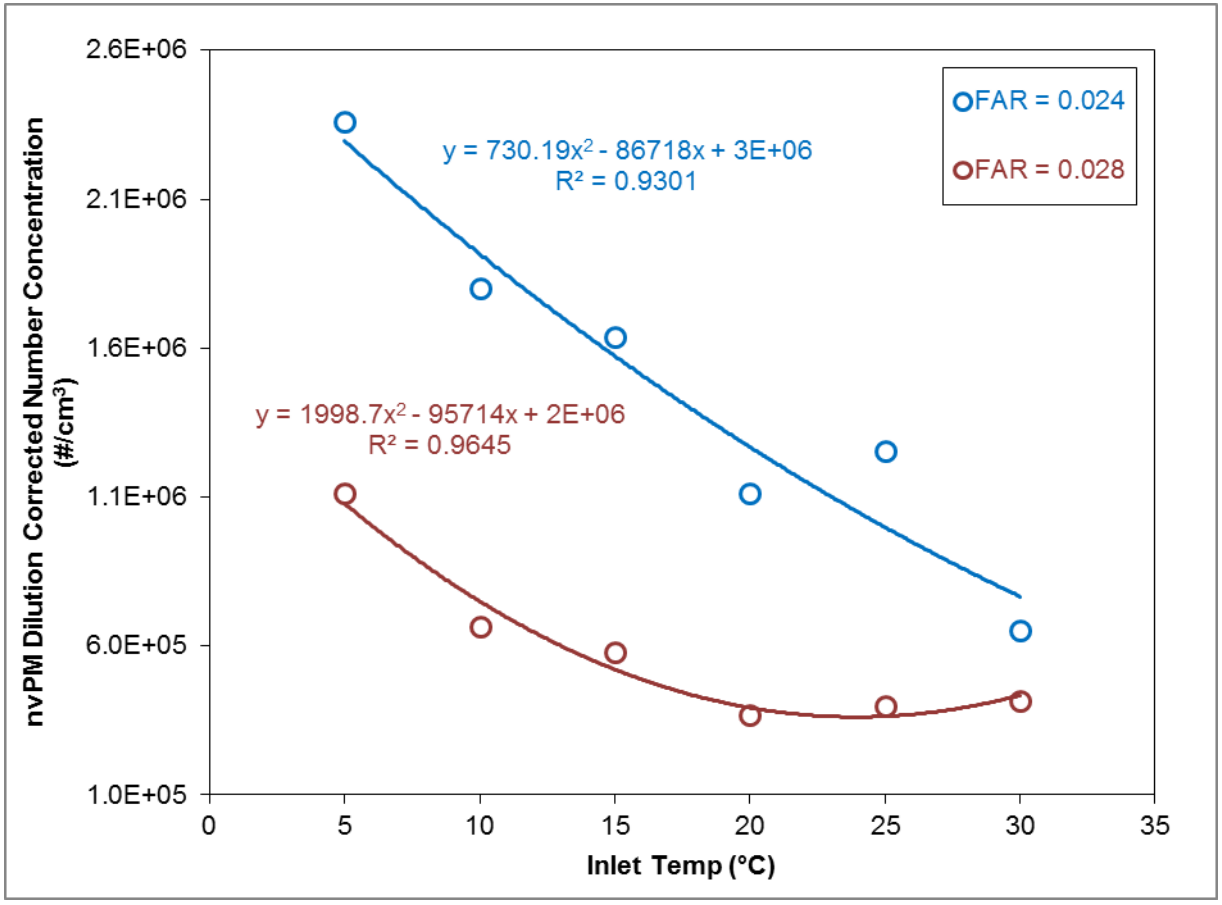
- nvPM concentration data was reduced and averaged over each test point

- Dilution corrected nvPM number and mass concentration data was analyzed as a function of T3 for various P3 and FAR values

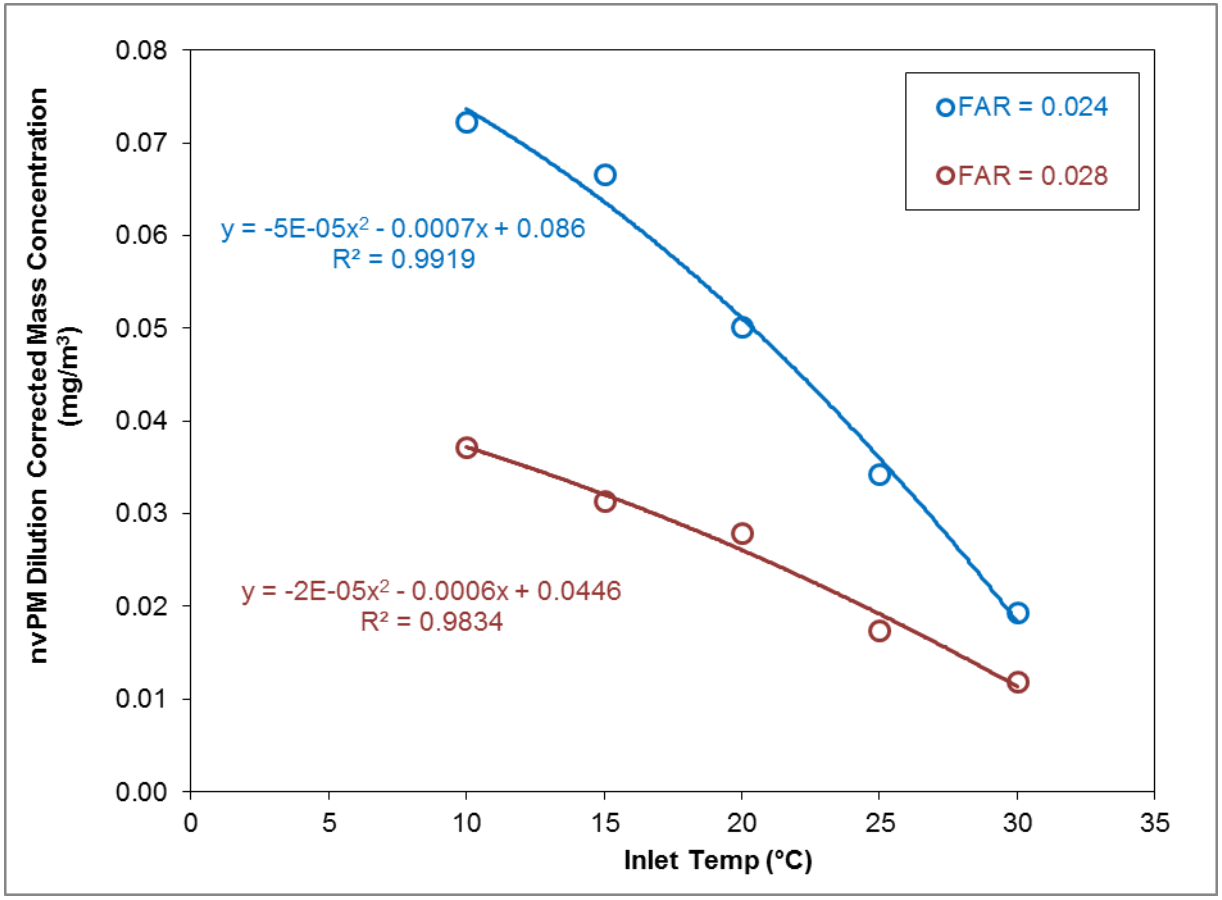
nvPM Number - Idle



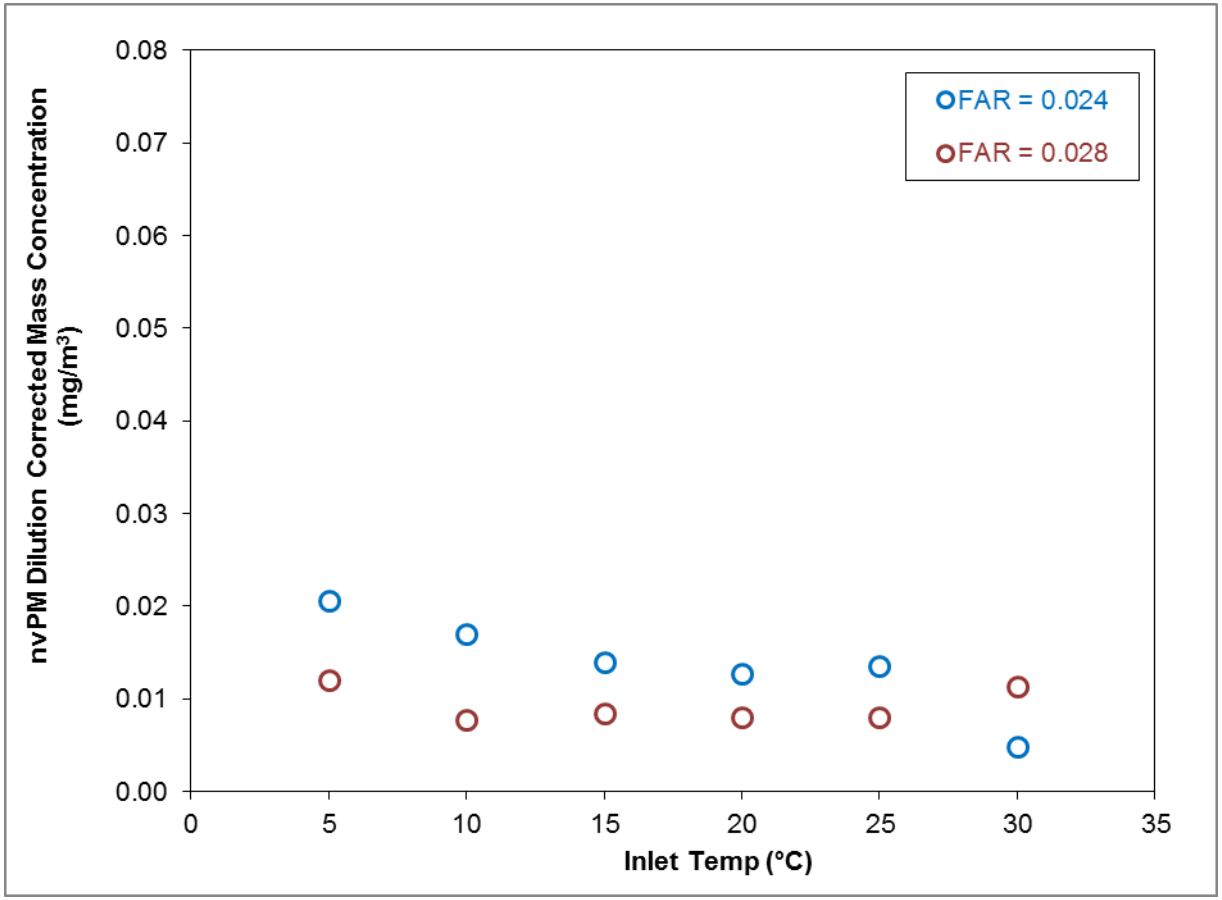
nvPM Number - Cruise



nvPM Mass - Idle



nvPM Mass - Cruise



Summary

- Successfully achieved test objectives
- Low nvPM number and mass concentrations:
  - at high T3-P3 settings
  - at fuel rich conditions
- Trends in nvPM number easier to track
  - higher signal to noise ratio
- Strong influence of T3 on nvPM number and mass
  - Smaller influence of FAR and P3
- Need additional data to develop correction factors for ISA