Advance Noise Control Fan II Test Rig Fan Risk Management Study

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NASA Glenn Research Center
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Background Information

- Since 1995 the Advanced Noise Control Fan (ANCF) has significantly contributed to the advancement of the understanding of the physics of fan tonal noise generation.

- The 9’x15’ WT has successfully tested multiple high speed fan designs over the last several decades.

- This advanced several tone noise reduction concepts to higher TRL and the validation of fan tone noise prediction codes.
Current GRC Facilities

Capabilities of current GRC Fan Noise Test Facilities

- **ANCF @ AAPL (TRL 2-3):**
  
  Low speed / ultra-low pressure rise / unique acoustic measurements 
  / limited aero measurements / high flexibility / parametric studies
  / low cost

- **UHB @ 9x15 LSWT (TRL 4-5):**
  
  High speed / pressure rise / aero & performance measurements / acoustic measurements w caveats / forward flight effects / point design / high cost

- **W8 (TRL 4):**
  
  High speed / pressure rise / aero & performance measurements / moderate costs
NEED:

A new Fan Test Rig to bridge from TRL 3 to 5 enabling the successful completion of NASA/Industry noise reduction program goals.
Test Rig Requirements

What would it look like?
(High level design requirements)

• All electric drive to minimize external support ($) (consider alternatives)
  - Minimize component noise level (initial metric > 20? dB below WT)

• Tested designs transferable to 9x15 WT - 22” fan diameter*
  - (suggested actual hardware a plus)

• Maintain current measurement capabilities.
  - Far field, in-duct, wall pressures, flow diagnostics, aero-performance

• Sited in AAPL - Minimal impact on existing rigs
  - Ambient temperature conditions

• Static - no external flow lines to complicate / no forward flight effects
ANCF II Location in AAPL

Proposed location of the new test rig with respect to current facility layout.

Former PLR stand & mezzanine
Background Information
Front Driven Fan- Test Rig Overview

Front Bearing Housing

Aft Bearing Housings

Speed Increaser

Jet Engine Fan Stage Hardware

Front Bearing Housing

Mid Bearing Housing

Mid Coupling (Not Shown)

Fan Drive Shaft

Aft Couplings

Electric Motor
Objective: Identify, prioritize and manage risks
Risk Management

- Programmatic Risks
- Technical Risks
- Schedule Risks
- Cost Risks

- Failure Risks
- Safety Risks
- Supportability Risks
- Environmental Risks
Risk Management Sequence

- Planning
- Identification
- Analysis
- Mitigation
- Monitoring

Feedback
<table>
<thead>
<tr>
<th>Work Area Description</th>
<th>Issue(s)</th>
<th>FY12 Status</th>
<th>FY 13 Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Management</strong></td>
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<tr>
<td>Coordinate Risk Reduction design</td>
<td>Current design has options that must be reviewed</td>
<td>High risk items identified</td>
<td>Develop design solution for high risk areas</td>
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<tr>
<td>Development efforts</td>
<td></td>
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<tr>
<td>Detailed Work Plan Development</td>
<td>Funding limitations for FY13, resource planning and estimated costs</td>
<td>Elements of work plan exist, but need to be</td>
<td>Improved fidelity of work plan required</td>
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<td></td>
<td></td>
<td>updated and organized</td>
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<tr>
<td>PDR Request for Actions</td>
<td>PDR closure required</td>
<td>PDR action items identified</td>
<td>Resolve all open PDR Action Items</td>
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<tr>
<td><strong>Systems Engineering</strong></td>
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<tr>
<td>Update Requirements Document (baseline)</td>
<td>Requirements document needs to be baseline for PDR completion</td>
<td>Requirements Document draft complete</td>
<td>Update Requirements Document and baseline for PDR closure</td>
</tr>
<tr>
<td>Update Risk Mitigation Plan</td>
<td>High risk design development tasks have been identified and need to be</td>
<td>Risk Mitigation Plan draft complete</td>
<td>Update Risk Mitigation Plan and baseline for PDR closure</td>
</tr>
<tr>
<td>Document</td>
<td>documented</td>
<td></td>
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<tr>
<td>Update ANCF II Interface Control</td>
<td>UHB Drive Rig interfaces with ANCF II test hardware MUST be maintained</td>
<td>Interface Control features identified</td>
<td>Develop a draft document that controls interface features, and references common capabilities</td>
</tr>
<tr>
<td>Document</td>
<td>for desired capability to test on both rigs</td>
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<tr>
<td>Update Concept of Operations plan</td>
<td>The planned operation of a test rig can help drive some design requirements</td>
<td>A significant amount of operations input has</td>
<td>Complete a Concept of Operations Plan and baseline for PDR</td>
</tr>
<tr>
<td>(baseline)</td>
<td></td>
<td>been gathered from 9x15 and Dome test engineering teams</td>
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</table>
Risk Management Approach

1. Conduct risk brainstorming session
2. Identify top ten risks
3. Summarize each risk on Risk Capture Form
4. Analyze risks through Risk Analysis Form
5. Develop ordinal scales and score on Risk Matrix
6. Prepare Risk Mitigation Plan
7. Incorporate business rhythm for risk management
8. Update Risk Mitigation Plan as circumstances warrant
Top Identified Risks

1. Low experience powering fan from front
2. Front drive passes through ICD
3. Aft drive requires reconfiguration from baseline
4. Simultaneous data from front and aft
5. Fan exhaust damage
6. Fan exhaust data
7. Gear Box Noise
8. Conditioned Inlet Flow Interference
9. Gear Box Delivery
10. Fan Drive Bearing System
11. Fan Drive Shaft System
<table>
<thead>
<tr>
<th>Risk Title: Low experience powering fan from front.</th>
<th>Owning Requirement: AR1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escalation Level:</td>
<td>Risk Owner: Shook</td>
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<tr>
<td>Phase(s): PDR</td>
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**Risk Statement:**
Given that the experience level for providing power to the front of the fan is low, the chance of unseen technical issues is greater.

**Context:**
Engineering Risk

**Likelihood:** 2

**Consequence - Safe:** 0  **Perf:** 2  **Sched:** 4  **Cost:** 3

**Status:** Open, risk has been identified and no mitigation defined.
## ANCF II Top Risk List

**April 10, 2012**

### Legend
- ↘ Decreasing (Improving)
- ↑ Increasing (Worsening)
- ⇔ Unchanged
- $ Cost Threat (Level 1, 2, 3)

### Candidate Risks

<table>
<thead>
<tr>
<th>Rank</th>
<th>Trend</th>
<th>Title</th>
<th>Owning Team</th>
<th>Likelihood</th>
<th>Consequence</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>1- Low experience powering fan from front.</td>
<td>Des.</td>
<td>2</td>
<td>0 2 4 3</td>
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<tr>
<td>2</td>
<td></td>
<td>2- Front drive passes through ICD</td>
<td>Des.</td>
<td>3</td>
<td>0 4 4 4</td>
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<tr>
<td>3</td>
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<td>3- Aft Drive requires Reconfiguration from Baseline Design</td>
<td>Des.</td>
<td>4</td>
<td>0 3 2 4</td>
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<td>4</td>
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<td>4- Simultaneous Data from front and aft</td>
<td>Res.</td>
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<td>5</td>
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<td>5- Fan Exhaust Damage</td>
<td>Des.</td>
<td>2</td>
<td>3 0 3 3</td>
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<td>6</td>
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<td>6- Fan Exhaust Data</td>
<td>Des.</td>
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<td>0 3 3 3</td>
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<td>7</td>
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<td>7- Gearbox Noise Level</td>
<td>Des.</td>
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<td>8</td>
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<td>8- Gearbox Conditioned Inlet Air Flow Interference</td>
<td>Des.</td>
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<td>0 3 4 3</td>
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<tr>
<td>9</td>
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<td>9- Gearbox Delivery Schedule</td>
<td>Des.</td>
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<td>0 0 4 4</td>
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<td>10</td>
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<td>10- Fan Drive Bearing System</td>
<td>Des.</td>
<td>3</td>
<td>1 4 2 3</td>
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<tr>
<td>11</td>
<td></td>
<td>11- Fan Drive Shaft system</td>
<td>Des.</td>
<td>2</td>
<td>1 4 3 2</td>
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### Associated Risks

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## Fan Drive System

<table>
<thead>
<tr>
<th>Work Area</th>
<th>Issue</th>
<th>FY12 Status</th>
<th>FY13 Objective</th>
<th>FY13 Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan Drive (facility)</td>
<td>Long drive system at high speed, potential vibration problems</td>
<td>Preliminary design is complete and component level calculation satisfy mechanical requirements</td>
<td>Further develop the test facility drive design and complete detailed component and system mechanical analysis</td>
<td>Commercial vendors are supporting further development of the facility drive design, and analytical models are being used at component level to look at static and dynamic capabilities to meet design requirements; 25% complete</td>
</tr>
<tr>
<td>Fan Drive Shaft (mechanical)</td>
<td>Small diameter (3 in), 4 ft long, and rigid</td>
<td>Preliminary design is complete and component level calculation satisfy mechanical requirements, shaft proto-type made</td>
<td>Further develop Fan Drive Shaft design to eliminate any manufacturing or performance risks</td>
<td>Proto-type Fan Drive Shaft design based on performance requirements has been built, balanced and verification testing planned; 75% complete</td>
</tr>
<tr>
<td>Fan Drive Shaft Verification Tests</td>
<td>Analytical estimates need verified</td>
<td>Manufactured a proto-type Fan Drive Shaft, in-house technical support identified, and basic plans defined</td>
<td>Verification of Fan Drive Shaft design</td>
<td>Preparation for verification tests on proto-type shaft are nearly complete, with tests and documentation to follow; 75% complete</td>
</tr>
<tr>
<td>Fan Drive Shaft (aero)</td>
<td>Need better understanding of shaft impact on aero-acoustics in front drive configuration</td>
<td>Initial discussions with aero-acoustic contractors about our concerns</td>
<td>Confirm that final shaft design meets Research criteria/requirements</td>
<td>Provided aero analyst contractor SOW for evaluation of shaft design to determine aero impact on front fan drive; 25% complete</td>
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<tr>
<td>Fan Support Bearing Housing</td>
<td>High speed, high thrust loads, limited space, limited lube access</td>
<td>Detailed evaluation of greased packed rolling bearings shows severe limits on performance</td>
<td>Identify a Fan Shaft bearing alternative to grease packed rolling bearing option</td>
<td>Identified bearing options and their performance capabilities; conduct a study based on weighted criteria to select design solution; 100% complete</td>
</tr>
<tr>
<td>Fan Support Bearing System Prototype</td>
<td>Need to better understand commercial part limitations/options</td>
<td>Several bearing vendors and NASA experts have been consulted</td>
<td>Develop a Fan Shaft Bearing system that meets critical performance requirements with available commercial technology</td>
<td>Bearing study has been completed and a type/vendor selected; NASA team will work with vendor to develop proto-type design to test Fan Shaft Support bearing system performance; cost estimate is ROUGH and based on finding existing test facility</td>
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**Fan Drive System**
<table>
<thead>
<tr>
<th>Sunday</th>
<th>Monday</th>
<th>Tuesday</th>
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- **WEEK1**: Reqs Tech Panel Mtg.
- **WEEK2**: Risks Tech Panel Mtg.
- **WEEK3**: TPMs Tech Panel Mtg.
- **WEEK4**: ENGINEERING REVIEW BOARD

### Risks Items Due
- Monday
- Thursday

### TPMs Items Due
- Tuesday
- Thursday

### Reqts Tech Panel Mtg.
- Monday

### CM MTG
- Wednesday

### ENG CHANGE BOARD
- Friday

### Reqts Items Due
- Friday
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Summary
Have we addressed these basic concerns?

- Risk monitoring must be tailored to project needs
  - Integrate into Schedule
  - Track critical path in frequent management meetings
  - Update schedules accordingly

- Periodic Assessment
  - Discuss frequently in meetings
  - Update risk level as needed and monitor closely
  - Review prioritization accordingly by Team Leads

- Rigorous Risk Identification
  - Unidentified risks are show stoppers
  - Unidentified risks unmanageable
  - Use external peer review
Summary

• Most failures traced to original proposal
  • Minimize risk in proposal stage
  • Cost and Schedule dreams

• Programmatic interfaces
  • External risk is outside our control
  • It’s their problem not mine
  • Review prioritization accordingly by Team Leads

• Risk management consists of:
  • Contingency (unknown- unknown)
  • Engineering margins (known-unknown)
  • Reserves (unknown cost unknown)