COMET:
Colorado Mini Engine Team
Manufacturing Status Review
February 3, 2014

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Customer: Lt. Joseph Ausserer, USAF

University of Colorado
Outline

• Project overview
  ▫ Specific objectives
  ▫ Review of critical project elements
  ▫ Updates on critical issues from CDR and FFR

• Schedule
  ▫ Changes since CDR and FFR

• Manufacturing
  ▫ Relevant tasks

• Budget
  ▫ Procurement status
  ▫ Budget status
Project Overview
Project Description

• Design and build a Power Extraction Unit (PEU) for a JetCat P90-RXI mini-turbojet engine that will generate 500 Watts of electrical power at 24 VDC.

• Sponsored by Air Force Research Laboratory’s Aerospace Propulsion Outreach Program (APOP)
Objectives

• Level one
  ▫ PEU must generate 500 Watts of power at 24 Volts DC
  ▫ PEU must produce this power after the engine has been running no longer than 1 min 20 s, twice the average start up time
  ▫ Engine and PEU must be compatible with the WPAFB test stand

• Level two
  ▫ Reducing thrust by no more than 25%
  ▫ Increasing specific fuel consumption by no more than 50%

• Level three
  ▫ Adding no more than the weight than an equivalent battery pack with 30 minutes of power (8 lbs)
  ▫ Producing 500 W throughout the engine’s RPM operating range

• Level four
  ▫ PEU to be entirely external to the JetCat engine, making the most modular solution.
Updates on Critical Project Elements

• Electronics
  ▫ Combine motor controller and power regulation circuitry into one PCB

• Software
  ▫ Motor controller microcontroller
    • No longer using microcontroller, controlled with LabVIEW code and implemented with DAQ I/O module
  ▫ LabVIEW testing VIs
    • Using JetCat’s Jetronics software for additional measurements
  ▫ Add rotor dynamic analysis
Updates on Critical Project Elements

• Mechanical
  ▫ Attaching starter to engine housing
    • Rigid harness to hold starter/generator in line with engine, no longer using brackets
  ▫ Mounting engine to test stand
    • No longer manufacturing our own clamps
    • Will use clamps that came with JetCat engine

• Off-ramp using low speed alternator attached to engine with flexible shaft coupling
  ▫ Spin up engine with compressed air
Schedule
Current Schedule Status

• **Systems:**
  ▫ Preparing for baseline characterization test
  ▫ At risk – precipitation may prevent test
  ▫ Allotted 7 day margin

• **Mechanical subsystem:**
  ▫ 17% of scheduled tasks completed (23 tasks total)
  ▫ Procure P200 starter generator – at risk
    • Must receive starter generator from Germany by Monday, February 24
  ▫ Must complete 6 tasks prior to TRR
    • Assuming starter generator arrives: 6 tasks
    • Off-ramp: 11 tasks
Current Schedule Status

• **Electrical subsystem:**
  ▫ 22% of scheduled tasks completed (10 tasks total)
  ▫ Preparing for baseline characterization test and manufacturing circuit boards
  ▫ Must complete 7 tasks prior to TRR
  ▫ On track

• **Software subsystem:**
  ▫ 34% of scheduled tasks completed (7 tasks total)
  ▫ Preparing testing VI, rotor dynamics, and power regulation/motor controller system
  ▫ Must complete 7 tasks prior to TRR
  ▫ On track
# Work Breakdown Structure (WBS)

<table>
<thead>
<tr>
<th>Structures</th>
<th>Electrical</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Manufacture engine clamps for CU test stand</td>
<td>• Updated test stand with load cell, flow meter, DAQ</td>
<td>• MATLAB model of JetCat engine</td>
</tr>
<tr>
<td>• Baseline characteristic test</td>
<td>• Power dissipation system</td>
<td>• Testing VI for load cell and flow meter</td>
</tr>
<tr>
<td>• Manufacture engine harness</td>
<td>• Calibrated load cell and flow meter</td>
<td>• Rotor dynamics</td>
</tr>
<tr>
<td>• Manufacture coupling system</td>
<td>• Power regulation and motor controller system</td>
<td>• Power regulation/motor controller system</td>
</tr>
<tr>
<td>• Rebalance engine with starter generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>attached</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• [Off-ramp]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Update engine harness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Attach purchased coupling system</td>
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</tbody>
</table>

**Project Description**

- Critical Elements
- Logistics
- Future Work
Schedule Changes

- Delay in procuring engine at beginning of semester due to JetCat P80-SE being discontinued
- Waiting for confirmation from Air Force to use P90-RXI
- Waiting to receive starter generator from JetCat in Germany
- Outsource manufacturing the key slot of the coupling system (need sinker electric discharge machining)
- Account for manufacturing engine/starter harness
- Account for off-ramp schedule
- Create PCB for power regulation/motor controller
Manufacturing
Scope

• Electronics components
  ▫ Power regulation/ motor controller board
  ▫ Power dissipation board
  ▫ Starter/ alternator

• Software components
  ▫ Testing VIs
  ▫ Controller programming
  ▫ Rotor dynamics analysis

• Mechanical components
  ▫ Alignment harness
  ▫ Pin and slot shaft coupling
# Electronics Manufacturing: Components

<table>
<thead>
<tr>
<th>Component or Subsystem</th>
<th>Make vs. Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power regulator / motor controller PCB</td>
<td>Purchase (Outsource)</td>
</tr>
<tr>
<td>Power dissipation board</td>
<td>Manufacture</td>
</tr>
<tr>
<td>Motor controller</td>
<td>Purchase</td>
</tr>
<tr>
<td>NI data acquisition hardware</td>
<td>Borrow</td>
</tr>
<tr>
<td>Starter / Generator</td>
<td>Purchase</td>
</tr>
<tr>
<td>Motor (to be used as alternator)</td>
<td>Purchase</td>
</tr>
<tr>
<td>Three phase rectifier</td>
<td>Purchase</td>
</tr>
</tbody>
</table>

- **Note:** text in purple denotes off-ramp items
Electronics Manufacturing: Details

- PCB manufactured by Advanced Circuits
  - Based on schematics supplied by COMET in PCB Artist software
- Once COMET receives the board, components will be soldered on in soldering lab
- For power dissipation board
  - Manufactured in house
  - Brought to presentation
Electronics Manufacturing: Status

- **PCB**
  - Design completed
  - To be sent to Advanced Circuits February 4
  - Expect two week turn around time
  - Expected time for soldering components: 1 day
  - This subsystem will be integrated with starter/generator for subsystem testing and final testing

- **Power dissipation**
  - Complete
  - Functionality test was completed Saturday
  - Will be integrated at final system test
# Software Manufacturing: Components

<table>
<thead>
<tr>
<th>Component or Subsystem</th>
<th>Make vs. Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor dynamic analysis</td>
<td>Manufacture</td>
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<tr>
<td>MATLAB model validation</td>
<td>Manufacture</td>
</tr>
<tr>
<td>Testing VIs</td>
<td>Manufacture</td>
</tr>
<tr>
<td>Jetronics</td>
<td>Purchase</td>
</tr>
<tr>
<td>Controller programming</td>
<td>Manufacture</td>
</tr>
</tbody>
</table>
Software Manufacturing: Details

- **Rotor dynamic analysis**
  - Implement finite element analysis in MATLAB
- **Controller programming through DAQ**

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**Diagram**

- ECU V10
- Onboard microcontroller
- PWM
- Starter Motor
- New Starter/Alternator
- cDAQ/Labview
- Relays
- X-30 Pro motor controller

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**Project Overview**

**Schedule**

**Manufacturing**

**Budget**
Software Manufacturing: Status

• Rotor dynamic analysis
  ▫ Find natural modes of engine shaft and use information to ensure vibrational modes are not excited during operation
    • Will verify software using results from a Heidelberg University Doctoral Dissertation

• MATLAB model complete, only validation needed

• Testing VIs
  ▫ Load cell testing VI complete
Software Manufacturing: Status

• Jetronics installed and operational
  ▫ Used for fuel flow measurement
• Controller programming
  ▫ Will use cDAQ with NI 9401 chasses
    • Chasses is bidirectional which will allow for motor control
  ▫ Preliminary design complete
  ▫ Necessary to switch between starting and generating circuitry and to drive the start
  ▫ Began Labview programming this week
# Mechanical Manufacturing: Components

<table>
<thead>
<tr>
<th>Component or Subsystem</th>
<th>Make vs. Purchase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot in engine shaft for connection pin</td>
<td>Outsource</td>
</tr>
<tr>
<td>Harness for alignment</td>
<td>Manufacture</td>
</tr>
<tr>
<td>Balance engine after shaft slot is finished</td>
<td>Outsource (JetCat)</td>
</tr>
<tr>
<td>Engine to alternator coupling</td>
<td>Purchase</td>
</tr>
</tbody>
</table>

- Shaft slot will be cut using an Electric Discharge Machine by Rapid Tooling
- Engine will be rebalanced by JetCat USA
- Note that the purple text denotes part of the off-ramp system
Mechanical Manufacturing: Details

- **Harness**
  - Manufactured in house using precision milling
  - Make fine adjustments using screws
Mechanical Manufacturing: Status

• By end of this week, will make decision to pursue off-ramp or current design

• For current design
  ▫ Can begin manufacturing of harness next week
  ▫ Will send engine shaft for EDM mid February
  ▫ As soon as shaft is returned (approximately 2 weeks), get engine rebalanced (1 week)

• For off-ramp
  ▫ COTS shaft coupler simple clamp on system
  ▫ Only additional time constraint is shipping
  ▫ Harness will also be manufactured, as above
Financial Budget Status

<table>
<thead>
<tr>
<th></th>
<th>Allocated</th>
<th>Current Expenditures</th>
<th>Future Expenses</th>
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<tbody>
<tr>
<td>Project Budget</td>
<td>$5,000</td>
<td>$1,283.80</td>
<td>$1,705.95</td>
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<tr>
<td>Engine Budget</td>
<td>$2,500</td>
<td>$2,530.0</td>
<td>$0.00</td>
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</tbody>
</table>

- Two large expenses coming up
  - Outsourcing machining of engine shaft slot
  - Starter Alternator
- Currently $78.83 over predicted budget
- Still have $1,980.25 in margin.
Procurement Status

- **Item of Concern: Starter Alternator**
  - Must have confirmation of shipment from Germany by 2/7/14 (Friday)
  - If this is not met, then the off ramp will be taken

- **Total of 39 items expected to be purchased**
  - Total of 12 remain to be purchased
  - $1705.95 of purchases (599.99 for Starter Alternator)
Questions?