Carbon Fiber Technology Facility (CFTF) ARRA CAPITAL Project Overview

Timeline
- Funds received FY10Q2
- Scheduled finish FY13Q4
- Forecast finish FY13Q2
- Currently in equipment fabrication and installation

- Barriers addressed
  - Cost
  - Inadequate supply base
  - Manufacturability

- Interactions/ collaborations
  - Capital project – subcontractors
  - Future operation - extensive

- Project lead - ORNL

$34.77M Budget
- No cost share

All funds have been received
- ~ 47% of baseline costed thru Feb
- All subcontracts to US companies
CFTF is the Bridge from R&D to Deployment and Commercialization

Primary CFTF Objectives

| Demonstrate low-cost carbon fiber (LCCF) technology scalability with the last scaling step before full-scale commercial production | Produce quantities of LCCF needed for large-scale material and process evaluations and prototyping |

CFTF Mission and Capabilities are Unique to the World
Carbon Fiber Technology Center (CFTF) Snapshot

- Highly instrumented, highly flexible conventional carbon fiber line for “any precursor in any format”
- Melt-spun fiber line to produce precursor fibers
- Provisions for additional future equipment
- Produce up to 25 tonnes/year of carbon fibers
- Demonstrate technology scalability
- Train and educate workers
- Work in partnerships with industry
Equipment Scale

- Production line length: ~390 ft
- Equipment height: ~25 ft
Capital Project Executed per DOE Order 413.3b

- Project included in DOE Budget
  - Program funds

- External Independent Review (EIR) for Projects ≥ $100M
- Project funds

- EIR for Projects ≥ $750M

Initiation Phase → Definition Phase → Execution Phase → Transition/Closeout Phase

**CD-0**
Approve Mission Need
- Proceed with Conceptual Design
- Request PED funding
- Start monthly PARS & Quarterly Project Performance reporting

**CD-1**
Approve Alternative Selection and Cost Range
- Allow Expenditure of PED Funds for preliminary design
- Approval of long-lead procurement if necessary

**CD-2**
Approve Performance Baseline
- Establish Performance Baseline
- Continue design
- Request construction funding

**CD-3**
Approve Start of Construction
- Approve expenditure of funds for construction

**CD-4**
Approve Start of Operations or Project Closeout
- Allow start of operations or project completion

Actions Authorized by Critical Decision (CD) Approval

PED = project engineering and design
PARS is a DOE project tracking system

Approach
# Key Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Status</th>
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<tbody>
<tr>
<td>CD-0</td>
<td>Issued Aug 2009</td>
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<tr>
<td>Equipment RFP’s</td>
<td>Issued July 2010</td>
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<tr>
<td>Building lease</td>
<td>Awarded Oct 2010</td>
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<tr>
<td>NEPA documentation</td>
<td>Approved Jan 2011</td>
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<tr>
<td>CD-1/2/3 Approvals</td>
<td>Approved Mar 2011</td>
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<tr>
<td>Groundbreaking</td>
<td>Actual Apr 2011</td>
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<tr>
<td>Equipment contracts</td>
<td>Awarded Mar 2011</td>
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<td>Building “dry-in”</td>
<td>Required May-12, Actual Nov-11</td>
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<tr>
<td>Equipment fabricated</td>
<td>Required Mar-13, forecast Jun-12</td>
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<tr>
<td>Equipment installed</td>
<td>Required June-13, forecast Aug-12</td>
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<tr>
<td>Equipment operational</td>
<td>Required Sept-13, forecast Jan-13</td>
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<tr>
<td>CD-4</td>
<td>Required Sept-13, forecast Feb-13</td>
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# Procurement Strategy

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<thead>
<tr>
<th>System</th>
<th>Award</th>
<th>Pricing</th>
<th>Performer</th>
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<tr>
<td>Building</td>
<td>Competitive</td>
<td>Fixed price</td>
<td>R&amp;R Partners</td>
<td>Leased</td>
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<td>Support equipment</td>
<td>With building</td>
<td>Cost</td>
<td>R&amp;R Partners</td>
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<tr>
<td>Carbon fiber line</td>
<td>Competitive</td>
<td>Fixed price</td>
<td>Harper Int’l</td>
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<tr>
<td>CF equipment unloading</td>
<td>BOA</td>
<td>Cost</td>
<td>ESG Construction</td>
<td>Task order</td>
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<tr>
<td>CF line installation</td>
<td>Competitive</td>
<td>Fixed price</td>
<td>TBD</td>
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<tr>
<td>Melt-spun fiber line</td>
<td>Competitive</td>
<td>Fixed price</td>
<td>Hills, Inc.</td>
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<tr>
<td>MSF equipment unloading</td>
<td>Included</td>
<td>Fixed price</td>
<td>Hills, Inc.</td>
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<tr>
<td>MSF line installation</td>
<td>Included</td>
<td>Fixed price</td>
<td>Hills, Inc.</td>
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</table>

CF = carbon fiber  
MSF = melt-spun fiber  
BOA = Basic ordering agreement

All subcontractors are US companies

Approach
CFTF is Located in an Industrial Park

Horizon Center

~15-minute drive

Highly accessible to industrial partners, with opportunity to locate other facilities nearby

42k sq. ft. leased building – 10 year lease

Offices, labs, mechanical, high bay

Approach
Capital Project is ON BUDGET and SCHEDULE

- Thru February, MIE budget tracking within 2% of baseline spending profile
- Unused contingency is 26% of unspent baseline
- Building is complete
- CD-4 forecast Feb 2013 vs. baseline Sept 2013
- Estimated equipment arrival dates:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Date</th>
<th>Equipment</th>
<th>Date</th>
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<tbody>
<tr>
<td>Ox Oven Stack 1</td>
<td>4/20</td>
<td>Ox Oven Stack 2</td>
<td>6/6</td>
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<tr>
<td>LT Furnace</td>
<td>4/17</td>
<td>HT Furnace</td>
<td>5/4</td>
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<tr>
<td>Post Treatment</td>
<td>5/1</td>
<td>Material Transport</td>
<td>5/23</td>
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<tr>
<td>Thermal Oxidizer</td>
<td>4/26</td>
<td>Melt Spinner</td>
<td>6/20</td>
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</table>

LT = low temperature, HT = high temperature, ox = oxidation
Building

Beneficial occupancy Nov 2011
Trim & finish completed Mar 2012

Accomplishments

Photos courtesy of RRP, LLC
Carbon Fiber Line – Tow Transport

• Capabilities:
  – Spooled tow, with plans to add boxed tow feed
  – Up to 24 tows in 3k – 24k sizes
  – 80k maximum tow size with less tows
  – Six draw/tension units
  – Driven passback rolls on oxidation ovens
  – 12” wide web conveyance

• Factory testing Apr 17 (tow drives), Apr 19 (creel), and May 3 (winder)

Creel
Photos courtesy of Izumi International and Harper International

Accomplishments
Carbon Fiber Line – Oxidation Ovens

- **Capabilities:**
  - 400 °C temperature rating
  - Four thermal zones
  - Parallel, cross, or down-flow (first in the world)
  - Sulfur-compatible zone
  - Tow and web material forms

- **Factory testing completed Mar 29**
Carbon Fiber Line – Carbonization Furnaces

• Capabilities:
  – 1,000 °C and 2,000 °C temperature ratings, respectively
  – LT furnace corrosion resistant with fiber activation capability
  – Tow and web material forms

• Factory testing Mar 27 (LT furnace), Mar 28 (HT furnace mechanical), and Apr 9 (HT furnace electrical)
Carbon Fiber Line – Post Treatment

• Capabilities:
  – Electrolytic surface treatment
  – Space allocated for future dry surface treatment
  – Sizing for aerospace and commodity resins

• Factory testing Apr 10

Photos courtesy of Harper International
Melt-Spun Fiber Production Line

- **Capabilities:**
  - > 10 kg/hr throughput
  - 2,000 m/min tow speed
  - 12” wide web direct-fed to carbon fiber line
  - Runs most melt-stable polymers, rated to 450°C
  - Multi-component filaments

- Equipment fabrication and assembly proceeding on schedule for factory testing and shipment in June

Platform assembly

Accomplishments

Mounted spinhead assembly

Screw & barrel

Photos courtesy of Hills, Inc.
Hazard and Operability Analysis Completed

- Describe system (unit operation)
- Postulate loss scenarios (sequences of events leading up to potential or actual losses, incidents or accidents)
- Define Risk = severity + likelihood
- Evaluate controls, barriers, safeguards
  - Planned/existing
  - Additional
- Over 75 actions were documented and being tracked to closure

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<table>
<thead>
<tr>
<th>Risk Ranking</th>
<th>Severity</th>
<th>Likelihood</th>
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<tr>
<td>A (Slight)</td>
<td>4</td>
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<tr>
<td>B (Moderate)</td>
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<tr>
<td>C (Severe)</td>
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<td>3</td>
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<td>D (Catastrophic)</td>
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CFTF Engages the Composites Value Chain to Develop/Validate Low-Cost CF Composites Matls & Mfg Technologies & Grow the Supply Base

RAW MATERIALS → PRECURSOR FIBERS → CONVERSION → COMPOSITE FORMULATION → TESTING & PROTOTYPING → APPLICATIONS

- PAN Textile, HMW, SAF
- PAN Melt-spun
- Polyolefin
- Lignin

Advanced Conversion Processes:
- Solution Spinning
- Melt Spinning
- Microwave Assisted Plasma
- Atmospheric Pressure Plasma
- Plasma Surface Treatment
- Highly Flexible Thermal Process
- Resin Design
- Matrix Formulation
- Pre-pregging
- Weaving
- Pre-forming
- Molding
- Filament Winding
- Curing
- Etc.

Testing And Prototyping

STRUCTURAL
- Vehicles
- Wind
- Defense
- Aerospace
- Oil & Gas
- Infrastructure

NON STRUCTURAL
- Flame Retardant
- Energy Storage
- Filtration
- Thermal Mgmt.
- Electrodes

End Users provide ORNL with cost & performance specs

Collaboration

LM003
Collaboration in Workforce Training
Mission Area Beyond ARRA Capital Project

Pool of Candidates
- DOL grant funded
- Located at ORNL
- Industry focused training
- For qualified unemployed or under-employed

Technician Internship Program
- High-quality STEM learning experience
- Collaboration with researchers in field of interest
- Growth of S&T talent
- Hands-on experience on complex CF line
- Learn S&T underpinning ORNL research
- Develop skills directly transferrable to industry

Longer term Vision:
(i) Develop workforce training system for future carbon fiber manufacturing partners
(ii) Develop internship and other training programs from high school through university graduate level
Significant Industry Engagement is Ongoing

- Five *industry-led* proposals to Advanced Manufacturing Office’s Innovative Manufacturing Initiative include significant prototyping at CFTF
  - Polyolefin fibers (1)
  - Functional lignin fibers (1)
  - Textile PAN fibers (3)

- Serious discussions are ongoing with an equipment supplier on processing trials that will exploit unique CFTF capabilities

- We receive frequent inquiries and are in multiple discussions that cannot yet be termed “serious”
Plans for the Next Year

- Complete equipment fabrication & factory testing
- Complete equipment installation
- Conduct site acceptance testing for all unit operations and system commissioning
- Hire and train staff for commissioning
- Secure CD-4 approval and commence operations – forecast for Feb 2013
- Continue building and executing industrial partnerships
Summary

- CFTF is an essential asset for scaling and deploying low-cost carbon fiber technologies
- CFTF addresses cost, inadequate supply chain, and manufacturability barriers
- CFTF is a CAPITAL project and is currently within schedule and budget
- Within the next year, we expect to complete equipment fabrication, installation, commissioning, and commencement of operations
- CFTF is driving significant industrial and educational collaboration