# Carbon Fiber Pilot Plant and Research Facilities

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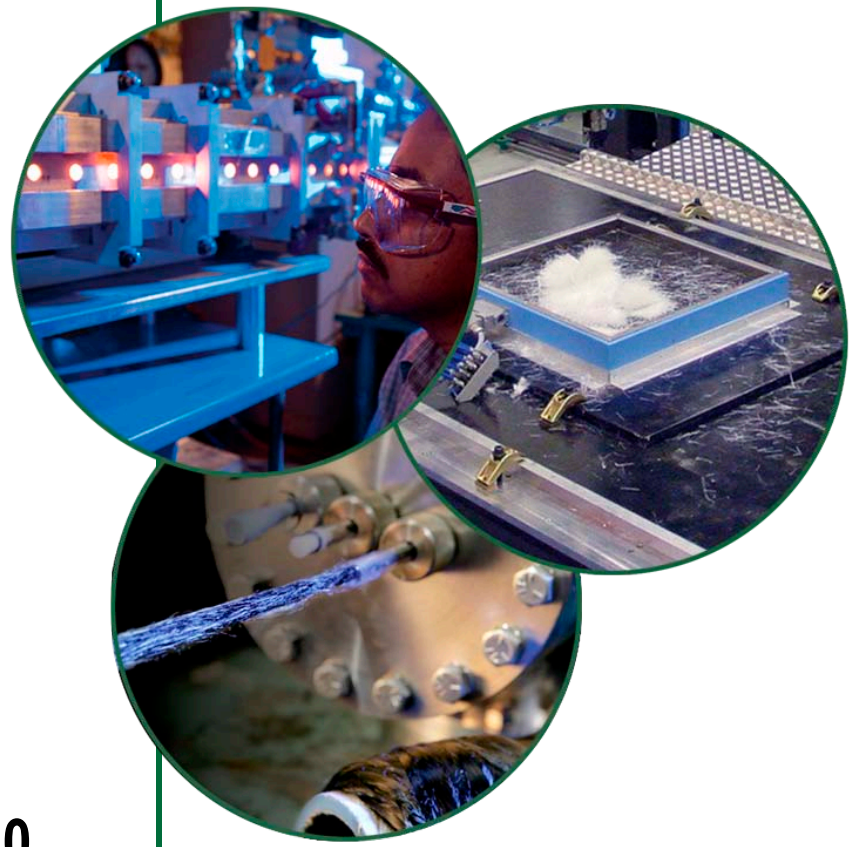

U.S. DEPARTMENT OF ENERGY

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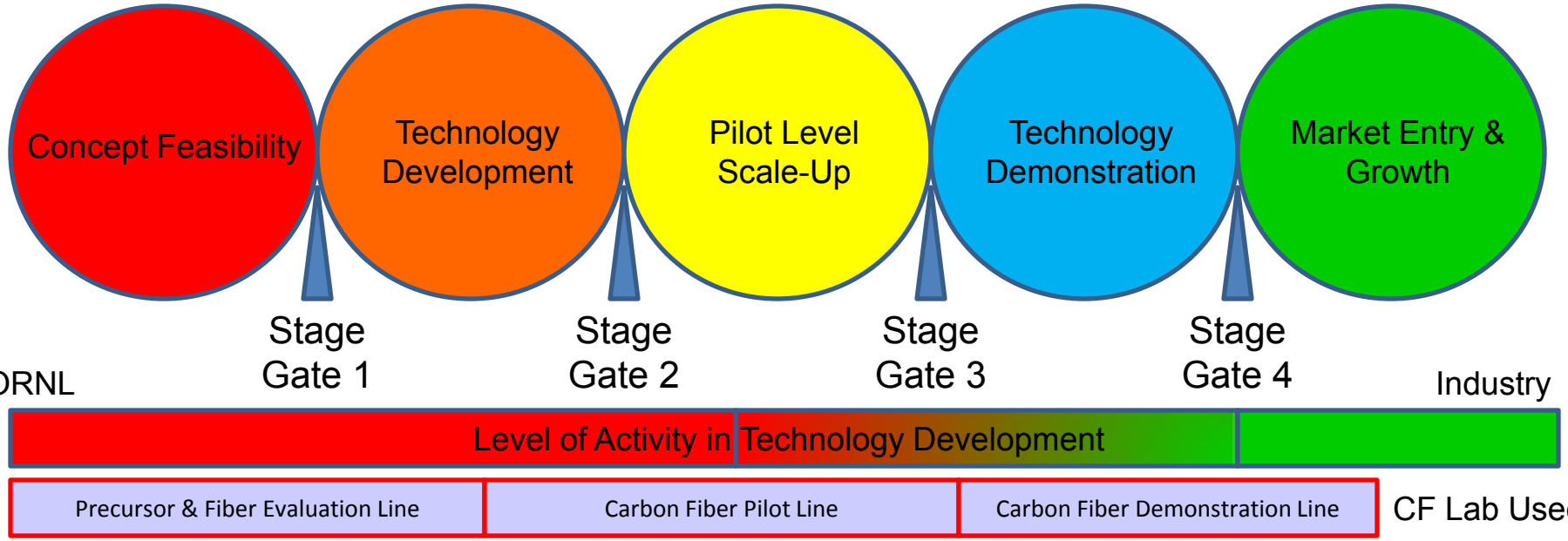
# Process for Carbon Fiber Technology Commercialization

## Materials




- Demonstrate technical feasibility
- Demonstrate likely cost effectiveness
- Bench scale
- Small material volume
- Batch processes
- Concludes with design of issue resolution plan

- Demonstrate technology works
- Demonstrate cost effectiveness if scaled
- Bench scale
- Small material volume
- Batch processes transitioning to continuous
- Concludes with design of prototype unit or materials

- Resolve continuous operation issues
- Develop continuous operation capability for short time periods
- Moderate material volume increasing as issues are resolved
- Concludes with design of continuous unit or final material selection

- Work to resolve full-scale equipment issues
- Develop multi-tow continuous operation capability for long periods of time
- Material volumes for product design and development
- Concludes with industrial adoption

- Industry adoption
- Product development
- Customer base development

# Carbon Fiber Facilities



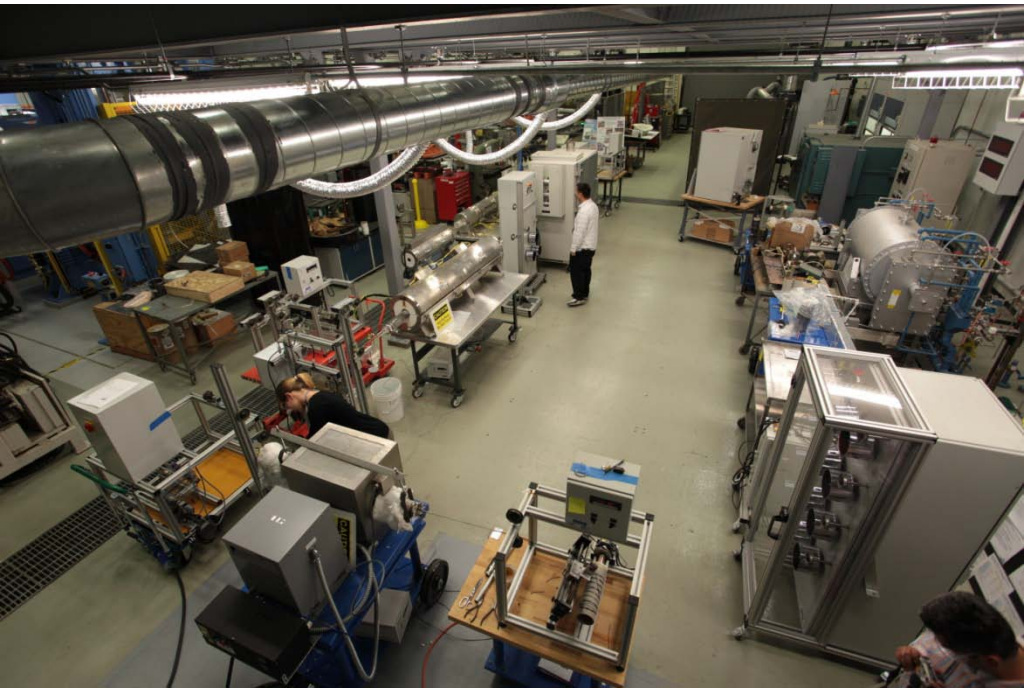
| Carbon Fiber Research Facility | Type Production | Fiber Types | Tow Size | Tensioning | Line Speed | Run Production Quantity | Annual Production Quantity | Intended Use |
|---|---|---|---|---|---|---|---|---|
| Lignin Facilities | Batch | Lignin | Small & Batch | None | Batch | few grams | N/A | Scientific Development of Lignin Precursors |
| Precursor and Fiber Evaluation Line | Continuous Fiber & Batch | Polymer Based and Continous Lignin | 1 - 50K Filaments; Single Tow | Precise for Small Tow | 1/4-5 in/min | Micrograms to 100 g | N/A | Scientific Development of Precursors; Small Volume; Conversion Process Development |
| Current Pilot Line | Continuous Fiber | Polymer Based | 3K-50K Filaments; 1-5 Tows | Limited | 1-16 in/min | 0.2 kg - 5 kg | 1000 kg | Quantities validating Precursor Development and Conversion Protocol; First Scaling Step |
| Carbon Fiber Demonstration Facility | Batch and Continous Fiber | All Types | 3K-80K Tows; Up to 24 Tows + Bulk Convenyance | Yes - High range of tensioning and stretching Control | 60+ in/min | up to 2000 kg | 25000 kg | Precursors and Advanced Conversion - Demonstrate Technology Scaling; Samples for Large Scale Material Evaluations |

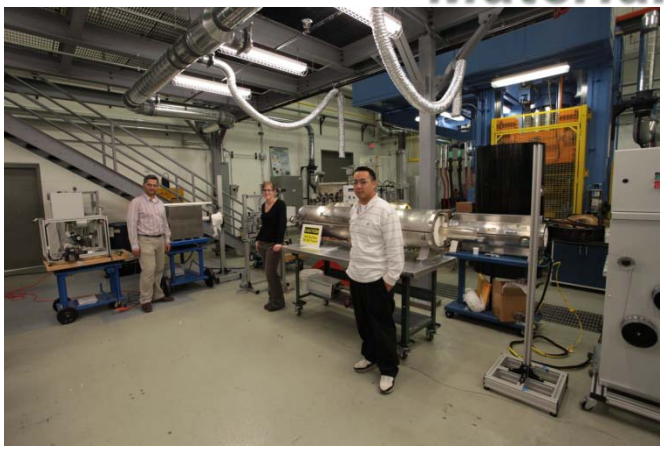
# Melt Spinning Facilities Installed at ORNL

## Compounding/Pelletization Line and Multifilament Melt Spinning Line

# Precursor & Fiber Evaluation Line







**Budget :** $200K/year

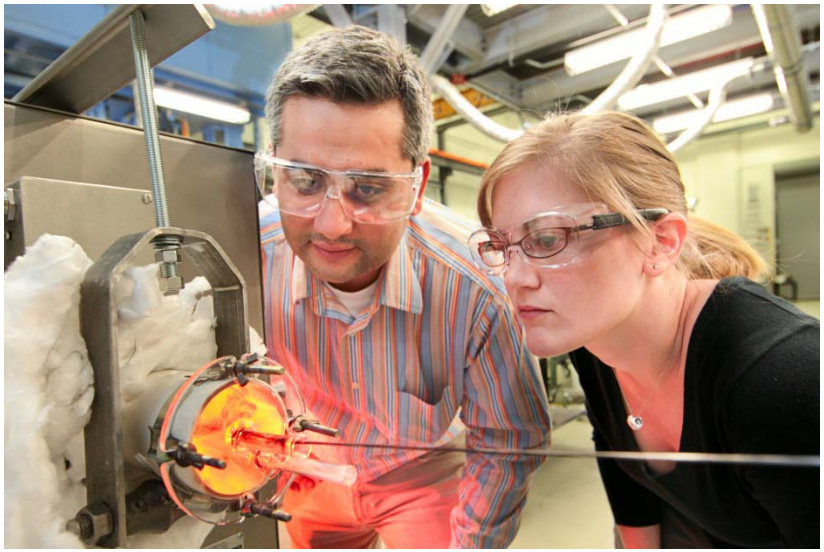
This has become our "workhorse" equipment system

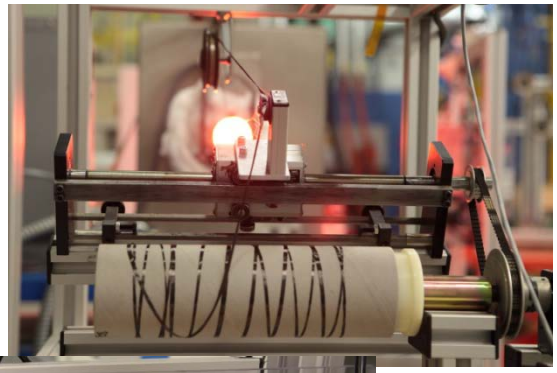
Some Equipment Provided by Mfrs

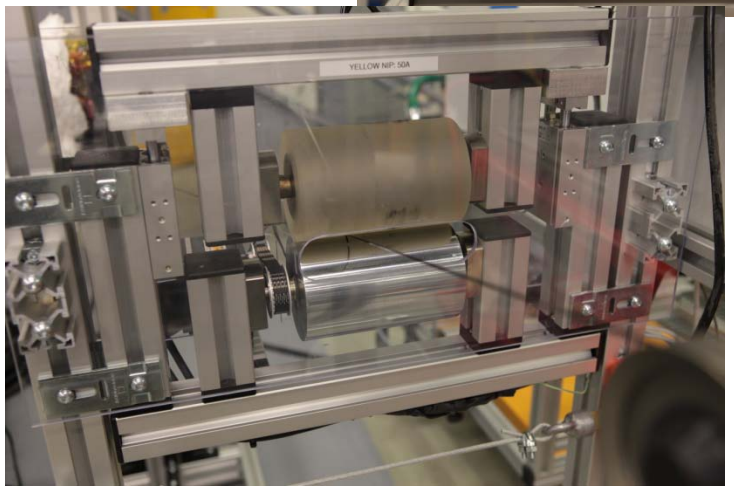
# Precursor Evaluation System



- Designed for development of conventional processing recipes with limited quantities of precursor
  - Residence time, temperature, atmospheric composition, and tension are independently controlled in each furnace
  - Can process single filament up to thousands of filaments
  - Precise tension control and stretching capability allows stretched/tensioned processing of ~20-filament tows
  - Temperature capability from room temperature to 1,700ºC; 2,500ºC furnace







# Special Capabilities

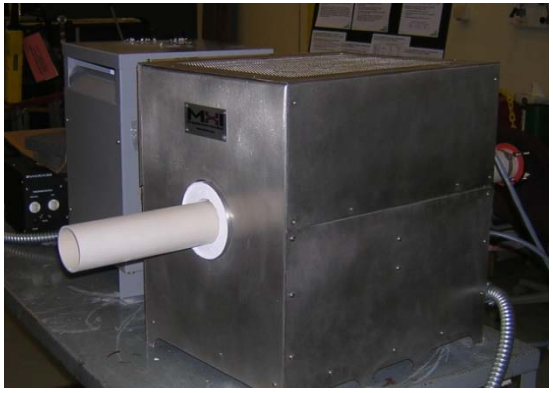


Laboratory Box Oven for Tow Oxidation

Low-Force Tension Controller

Dancing Tension Controller

New 2,500 ºC Furnace



New 1,750 ºC Furnace

# Conventional Pilot Line



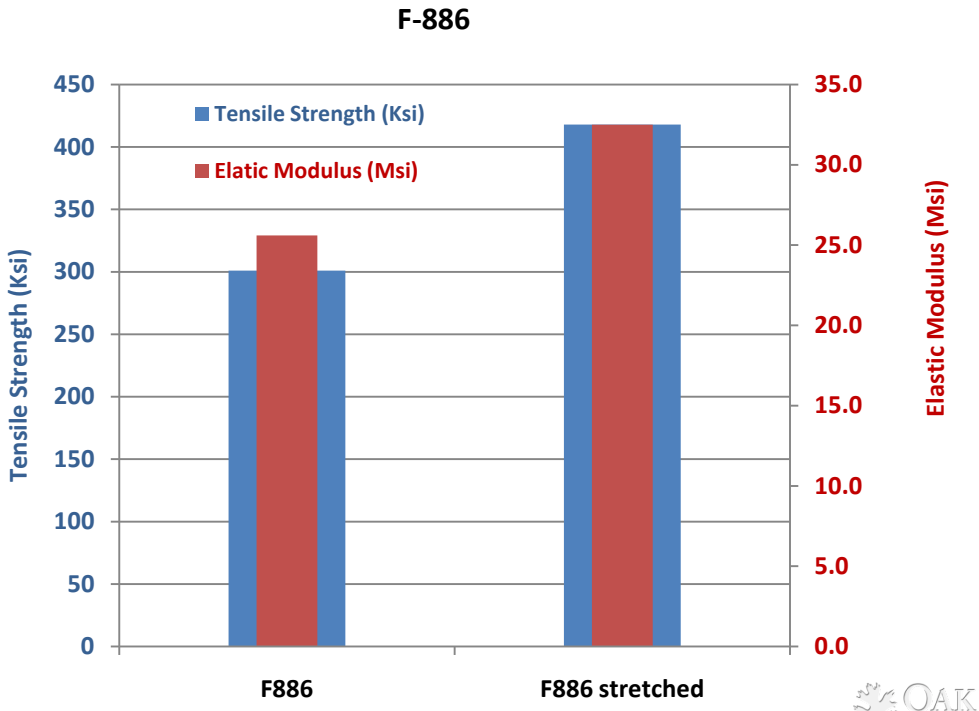
- 1:20 scale of a commercial grade production line
- Capacity for 8 tows
- Preferred tow size ≥ 3k

**Upgrade Needed to Better Develop Processing Protocols**

- Lack of progressive, controlled stretching capabilities in the oxidation stage.
- Fiber movement system: low speed, electronically antiquated.
- Pretreatment unit: designed to handle large precursor bands (e.g. Courtaulds, textile, etc.).
- Pre-stretching non-uniform and mainly "gear" to eliminate fiber crimp.

**An example of the Pre-stretching of the Textile Precursor:**

Thus during development, evaluated materials would appear to have lower properties than can be achieved in production.



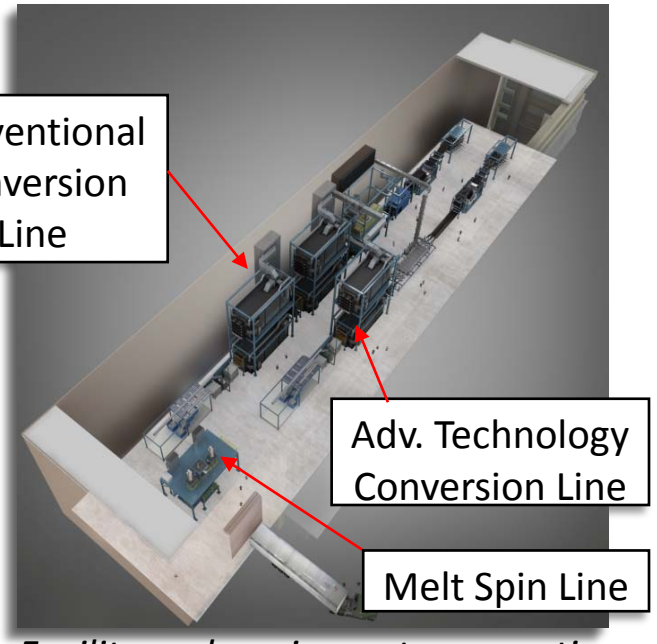
## NEEDED MODIFICATIONS

- Design and installed a progressive, controlled stretching system, mainly in first and second oxidation ovens.
- Modified tow flow patents/rollers to increase production line speed.
- Modified pre-treatment to take multiple spool (up to 6kg each) units.
- Add Conventional Surface Treatment Capabilities.
- Not Yet Scheduled

# Carbon Fiber Technology Center



- North America's most comprehensive carbon fiber material and process development capabilities
- Development and demonstration of carbon fiber technology for energy and national security applications
- Low-cost and high-performance fibers
- Fast, energy efficient processing
- Capability to evaluate micrograms of candidate materials and produce up to 25 tonnes/year of carbon fibers
- Produce fibers for large-scale material and process evaluations by composite manufacturers
- Train and educate workers
- Grow partnerships with US industry




*Facility and equipment perspective*

# CFTC Scope



- Highly flexible, “conventional” carbon fiber production line that can accept “any precursor in any format”
- Melt-spun precursor fiber production line with production capacity matched to carbon fiber line
- Space and utility provisions for the future addition of an advanced technology carbon fiber production line with similar capacity
- Consolidation and expansion of LCCF and carbon fiber composites R&D tools with emphasis in composites manufacturing

1. Precursor Spinning Line
2. Conventional Conversion Line

} Part of This Effort

3. Advanced Technology Line
4. Carbon Fiber Composites Fabrication

# Precursor Fiber Production Line

## Materials

- 70 tpa rated capacity
- Capability to produce lignin, polyolefin, and pitch precursor filaments; upgradeable for production of melt-spun PAN filaments
- Twin screw extruder with precursor compounding and master batch preparation capabilities
- Operation temperatures from 150 to 350°C
- 2500 to 6250 filaments per position with up to 8 spinneret heads per position
- Process-dependent ability to produce 1 to 1.5 denier per filament.
- Ability to produce designed filaments with varied filament morphology, including bi- and tri-component capability
- Spun-bonded nonwoven web production unit, up to 6000 ft/min, with conveyer belt and friction-driven winding devices
- Corrosion-resistant wetted surfaces for handling corrosive additives
- Three induction-heated Godet drawing units with controlled heating to 200°C and denier control stand
- Metered finish application, interlacing and cutter-aspirators

# Carbon Fiber Production Line

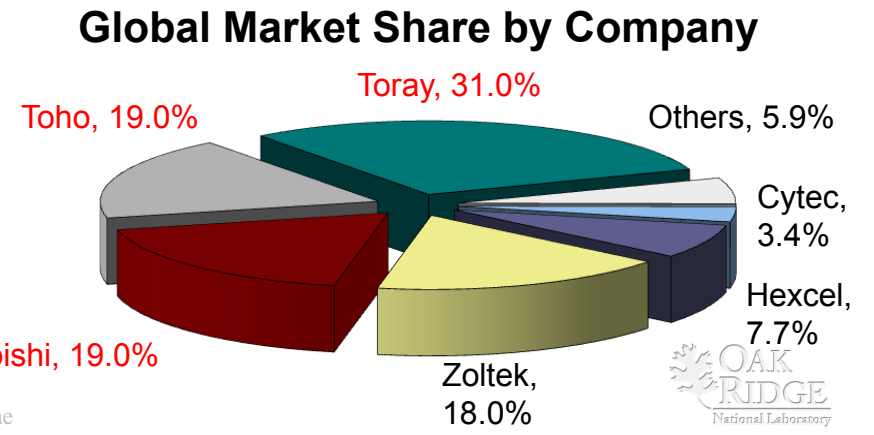
## Materials

- 25 tpa rated capacity
- Exceptionally wide temperature ranges in all ovens and furnaces
- Ability to feed precursor fibers from a creel, from boxes/bales, or in bulk product form
- Material transport in tow or bulk form
- Tow sizes from 3K to 80K.
- Enhanced stretching and tensioning capabilities, with significant differential stretching capability in the oxidation module
- Ovens, furnaces, and exhaust systems designed to handle effluent by-products and rates from PAN, lignin, polyolefin, pitch, and rayon precursors
- Low-temperature carbonization furnace designed to accommodate an oxidizing atmosphere
- Expansion slot to enable the addition of an ultra-high-temperature graphitization furnace for specialized carbon fibers
- Expansion slot for an additional surface treatment module
- Finished fibers spooled or packaged in mat or bulk form
- Fully integrated control system with data logging, web interface, and custom access to control room and all data displays

# Benefits

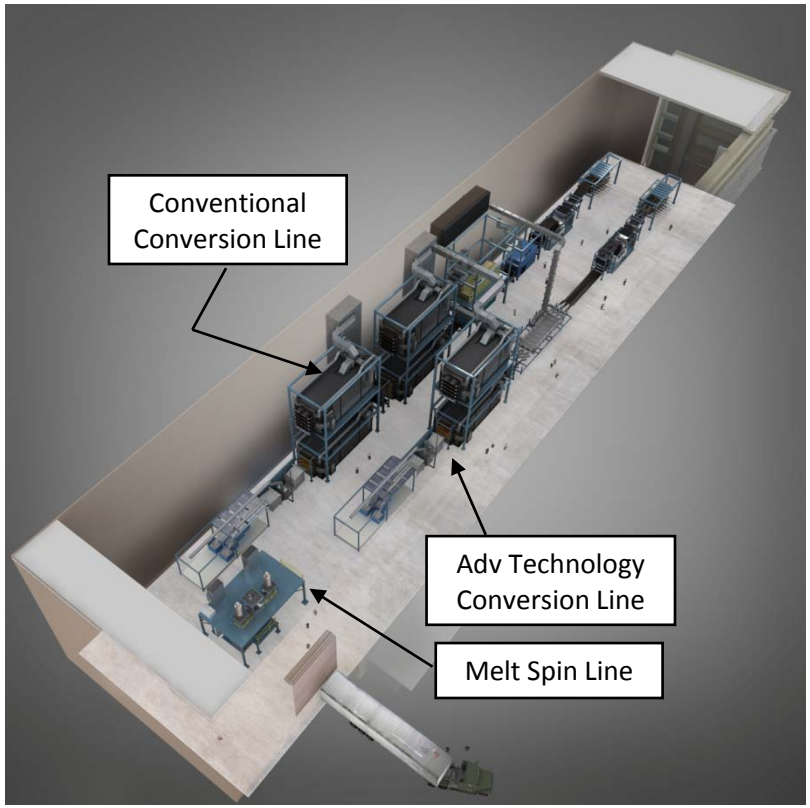
- Fills the need for a national center to demonstrate scalability of LCCF for automotive/truck, wind energy, oil and gas, and other energy applications
- Significantly accelerate the commercialization of LCCF technologies
- Demonstrate scalability of LCCF composites manufacturing processes
- Proprietary research capabilities
- Promote the development of Industrial partnerships and encourage vertically integrated teams
- Stimulate economic growth by job creation and workforce development, including student research
- Utilizes US based technologies and equipment

***Recapture technology and market leadership from the Japanese who currently control 70% of the global carbon fiber market***



# Approach

- Specify, design install, and commission a highly flexible, conventional carbon fiber conversion line of 25 ton/year capacity that can convert "any precursor in any format"
- Specify, design, install and commission a melt-spun precursor fiber production line of 50 - 145 ton/year capacity
- Conduct industry workshops to prepare facilities operational plan and schedule
- Design and construct infrastructure that meets operational requirements for the demonstration fiber production lines and the future advanced technology conversion line



# Facility will be a Center for Deployment



Precursor Spinning

Lignin
Textile
Polyolefins
Melt-Spun
Solution-Spun

Carbon Fiber Conversion

Advanced Stabilization
Advanced Oxidation
MAP Carbonization
Surface Activation
Alternative Material Forms
Provide Materials for Application Development

Application Development

Automotive
Wind Energy
Oil & Gas
Infrastructure
Power Transmission
H2 & NG Storage
Defense

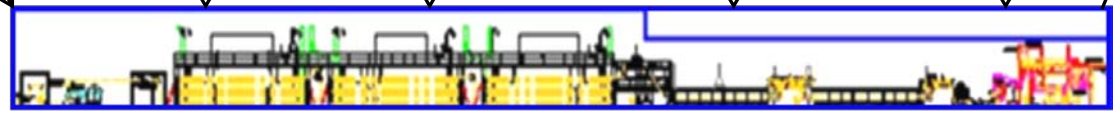
Alternative Precursors

Spinning Technology

Newly Developed Technologies

Interchangeable Subsystems

Application Development

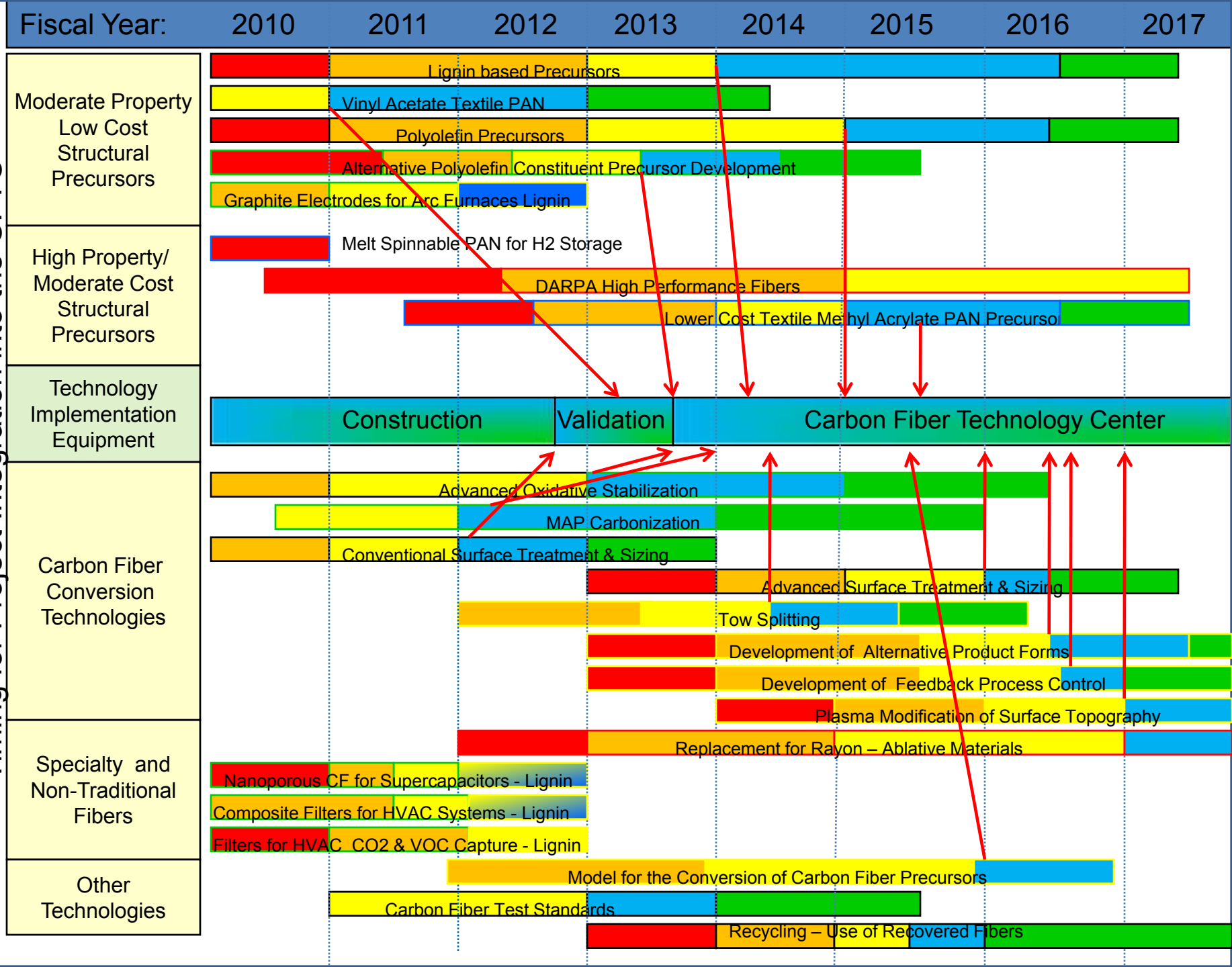


Conventional Technlogies

User facility will provide a forum for proprietary and non-proprietary work.
Location would have to be assessable to all with relevant technologies
Would provide the materials for application development targeted at HIGH Volume industries.

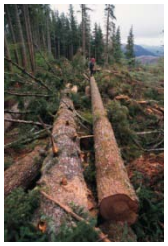
LM003

# Timing for Project Integration into the CFTC



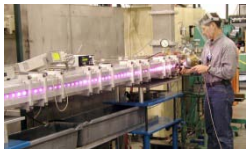
# Summary Technology Flow



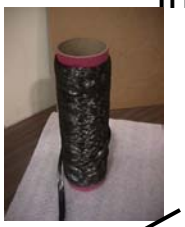


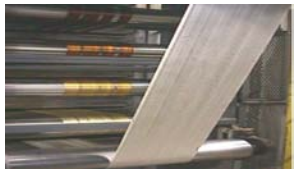
Alternative Precursors

Advanced Conversion Methods

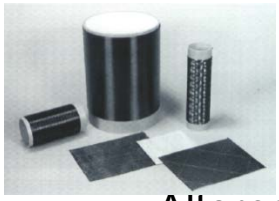


High Volume Industrial Plants





**Lower Cost Carbon Fiber**



Alternative Product Forms

Deployment Line Use

Multi-Material Compatibility

**Industry Affordable Material**

Hydrogen Storage

Wind Energy

Automotive

Infrastructure

**Component Development**

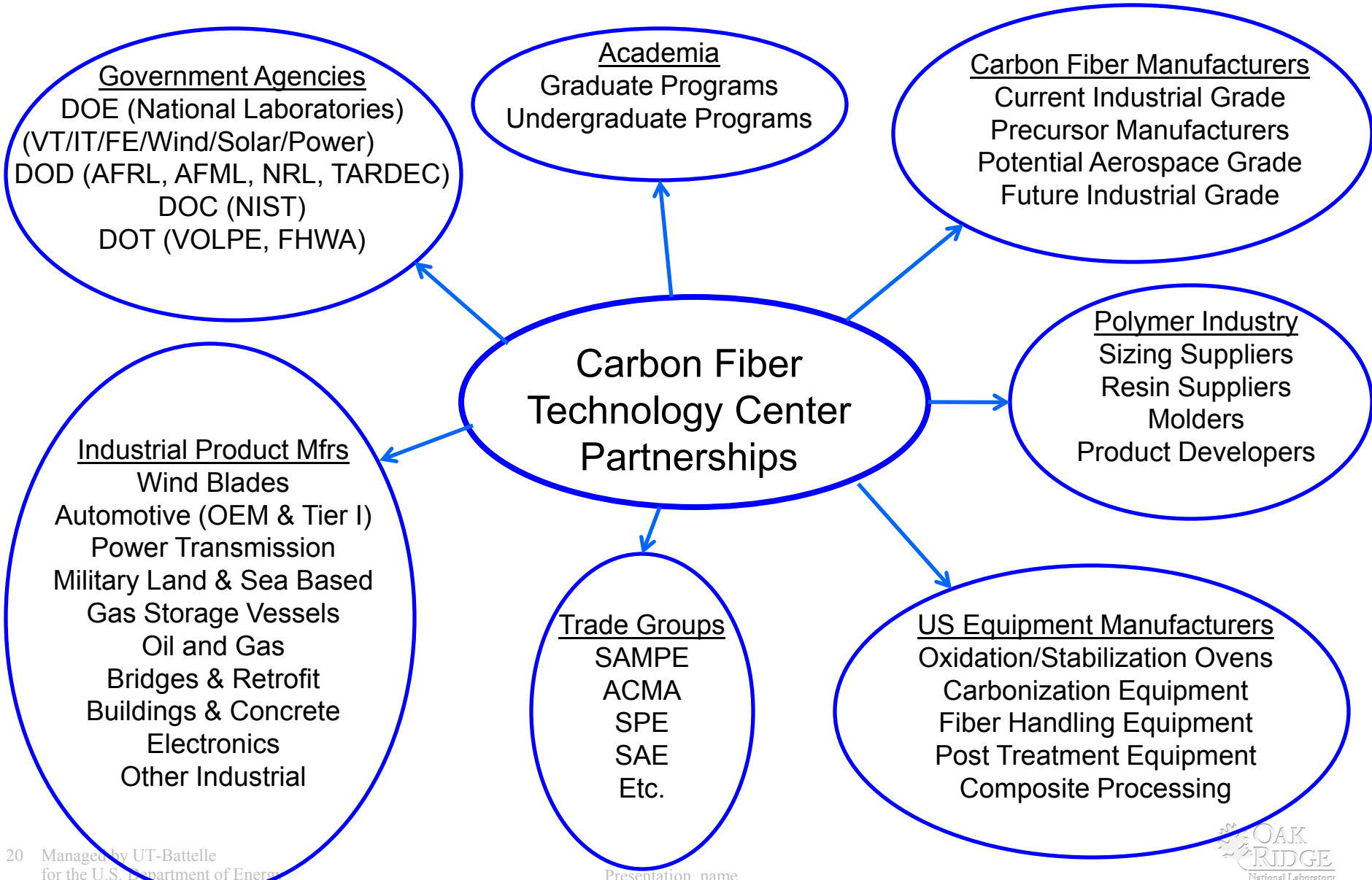
Defense

Fossil Energy

Power Transmission And Storage

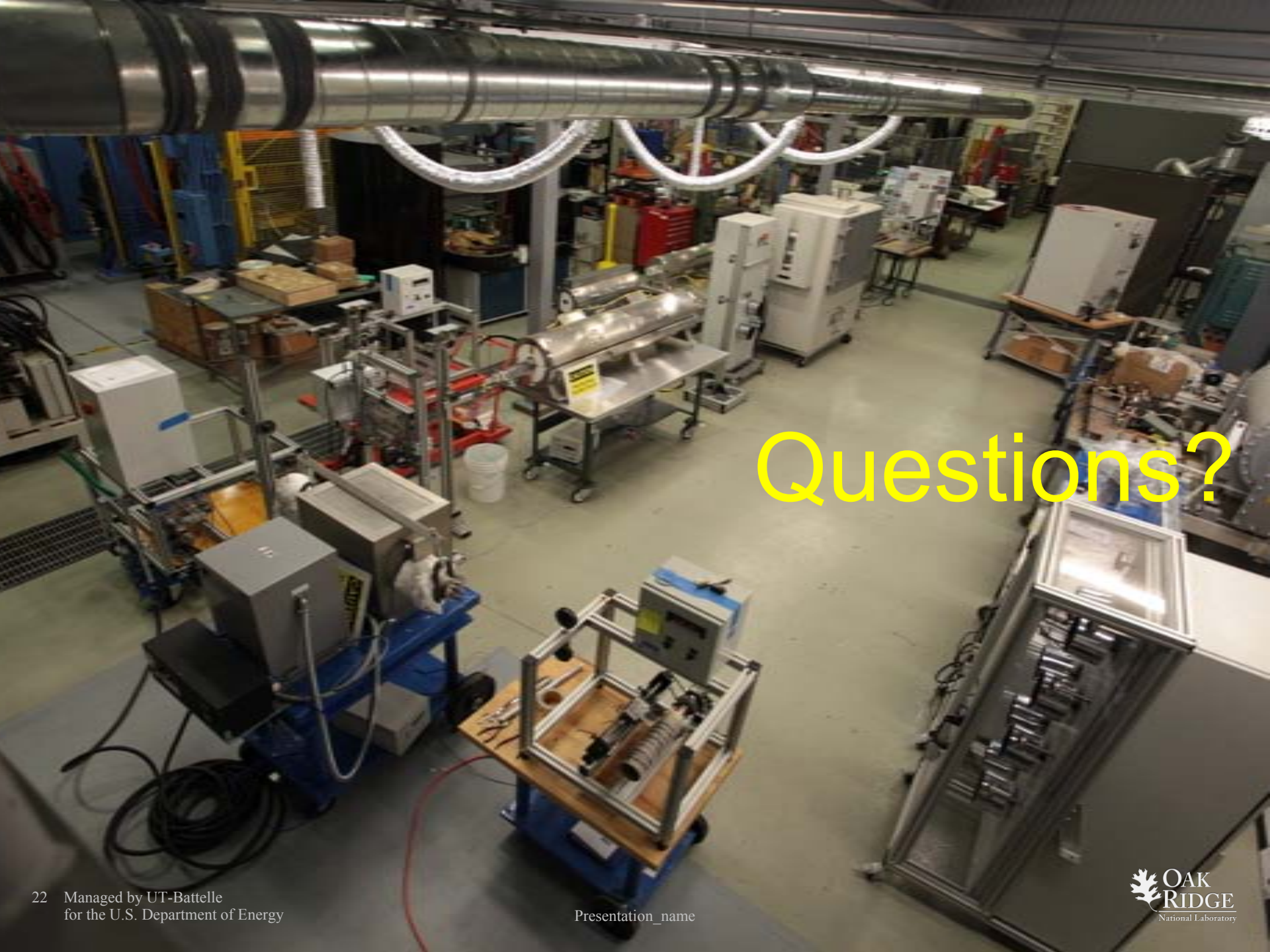
# Required Program Partnerships





# CFTC Project Management Plans

- **Project will be managed in compliance with ARRA requirements**
- **Budget Allocations** — **Awarded**
  - **Total** — **$ 34.7 M**
  - **Infrastructure** — **$ 14.7 M**
  - **Carbon fiber line** — **$ 14.0 M**
  - **Precursor fiber line** — **$ 6.0 M**
- **Critical Milestones and Decision Points**
  - **CD-0 Approve mission need** — **Oct 2009**
  - **Conversion line procurement award** — **Aug 2010**
  - **Begin building construction** — **Oct 2010**
  - **Precursor fiber line procurement award** — **Jan 2011**
  - **Building complete** — **Jan 2012**
  - **Equipment delivery** — **Feb 2012**
  - **Equipment commissioned** — **Sept 2012**


Questions?