DOE Hydrogen Program

# Inexpensive pressure vessel production through fast dry winding manufacture

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This presentation does not contain any proprietary or confidential information

# Overview

## Timeline

- Start date: **August 2008**
- End date: **August 2011**
- Percent complete: **20%**

## Budget

- Total project funding
  - DOE: **$400 k**
- Funding received in FY09:
  - **$150 k**
- Funding for FY08:
  - **$150 k**

## Barriers

**H. Lack of carbon fiber fabrication techniques**

## Targets

**2010 storage system cost**

## Partners

Ongoing joint project with composite/vessel manufacturers

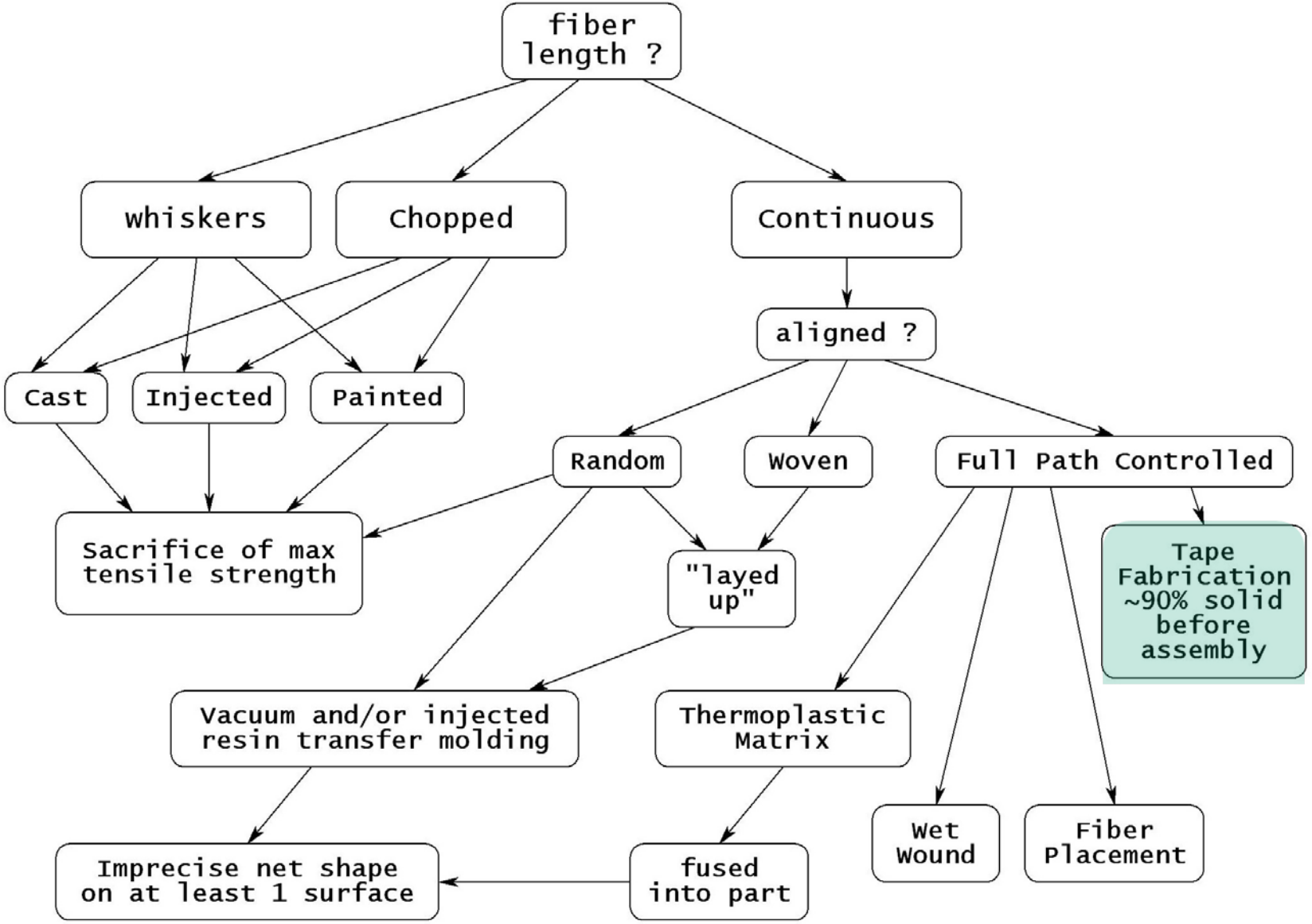
- **Quantum**
- **Boeing {PhantomWorks}**
- **PNNL**

# Objective: Reduce long-term hydrogen vessel cost to $4/kWh ($800 for 6 kg vessel) through innovative winding technology

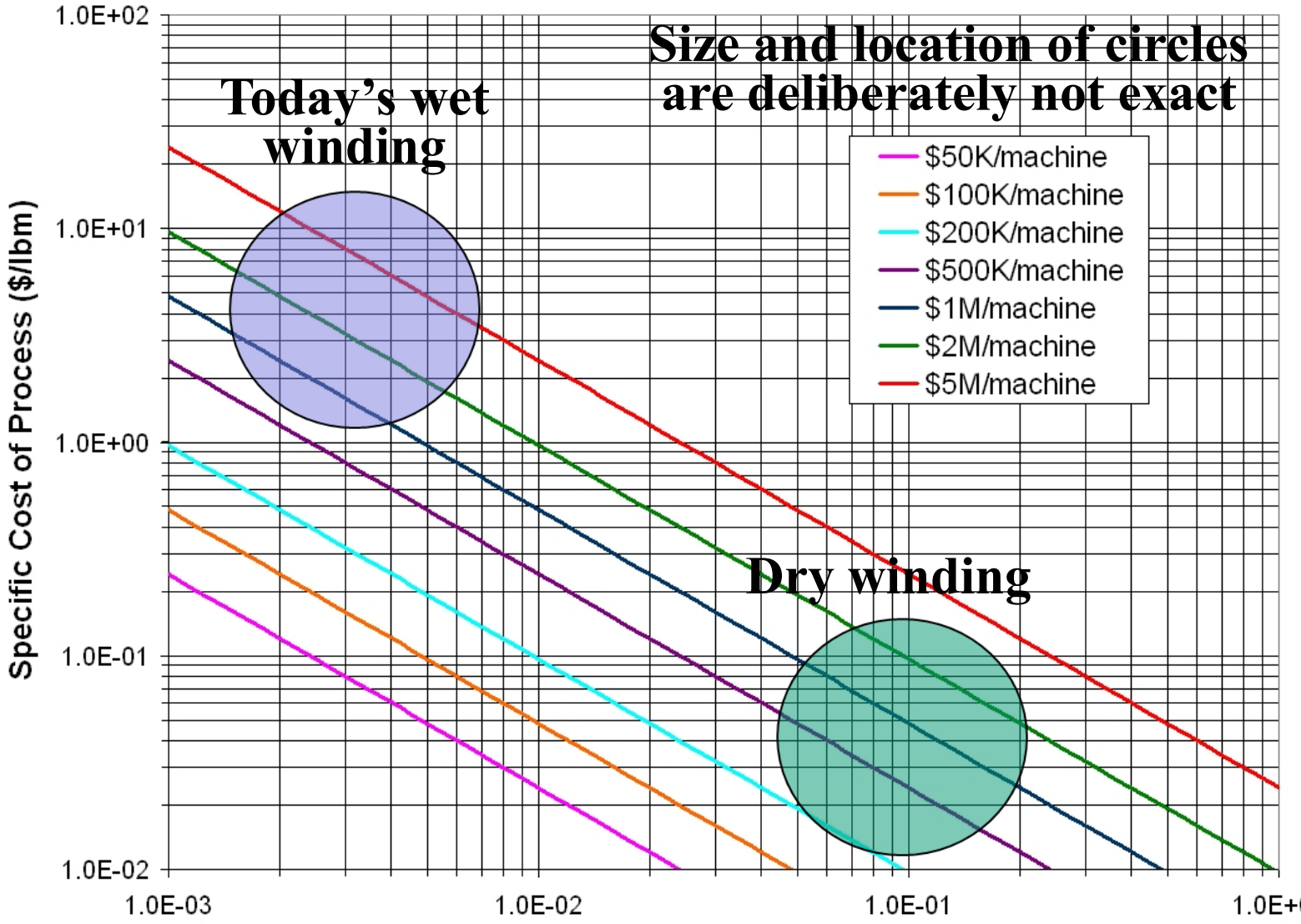
- **What do we mean by tape fabrication ?**

- **Much cannot be shown due to proprietary technology**

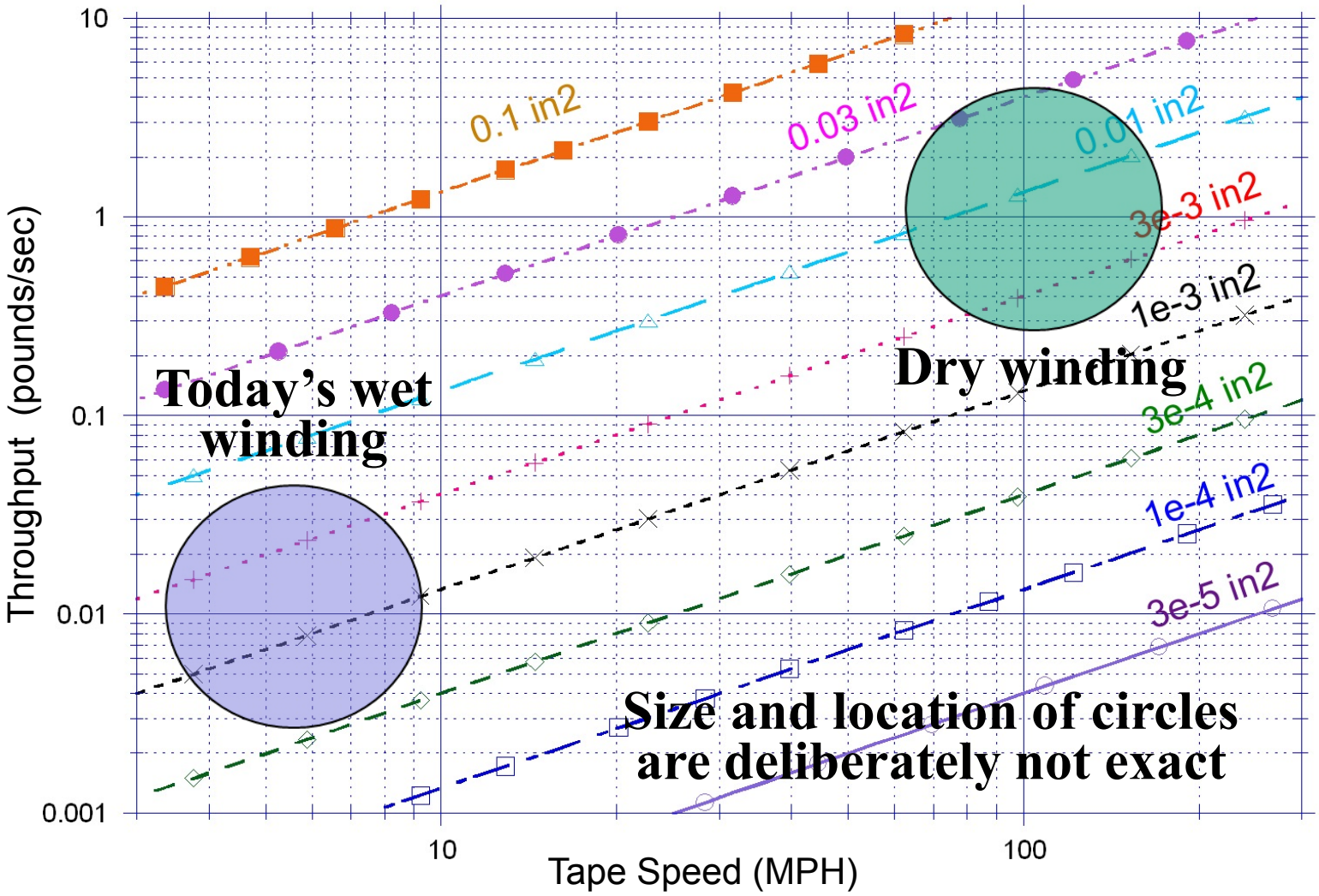
# LLNL patent pending tape fabrication technology retains high fiber strength through continuous fiber path control



# Approach: pressure vessel winding and curing is slow and expensive. We can reduce the cost through high speed dry winding operations



# Throughput is proportional to tape speed and cross sectional area
# Significant cost reductions require *fast* winding



# Accomplishments:

## Methodology is the subject of a recent LLNL record of invention.

## Enabling aspects of this invention are LLNL proprietary

## Will be released after patent application is published

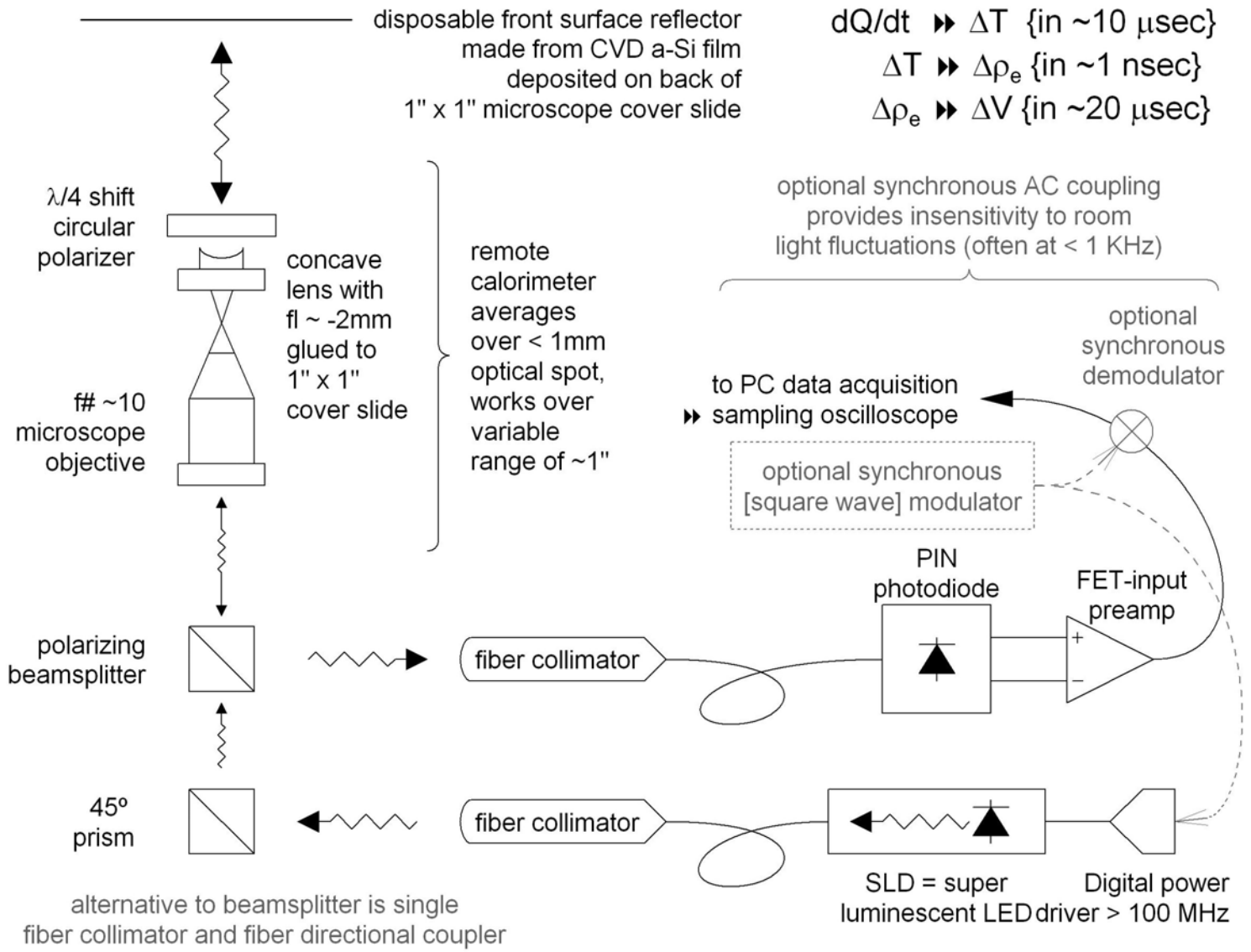
DOCKET: IL-11964

**METHODS FOR TAPE FABRICATION OF CONTINUOUS FILAMENT COMPOSITE PARTS AND ARTICLES OF MANUFACTURE THEREOF**

# We are making tape samples and will conduct experiments to determine bonding time

- **Time required to bond tape-to-tape is the essential unknown**
  - Can't design a bonding geometry to test process with unknown dynamics
  - So, measure bonding time by placing flat samples in planar contact
- **No available instrument can measure high speed bonding time**
  - Use available fast measurement sensors ➔ build them into an instrument
  - Point sensor at a 2-dimensional uniform bonded geometry
- **Avoid disposal of sensors to preserve response calibration**
  - Need to dispose of multiple one-shot bonding experimental samples without disposing of the fast sensor or altering its calibration
- **The most desired mechanical measurement is strength - but**
  - Can't interfere with choice or control of candidate bonding processes
  - Next most desirable is mechanical impedance (modulus) – but too slow since wavelengths and wavefronts too big for quasi-1D geometries
- **Measure time of bonding via its associated enthalpy change**
  - Rise time of a temperature transient measurement can be ~1 nanosecond
  - Electronics is fast enough, but connections are exotic, so go remote optical
- **Need ~5% repeatable dynamics of calorimeter thermal response,**
  - however can get by with crude temperature scale errors of ~30%

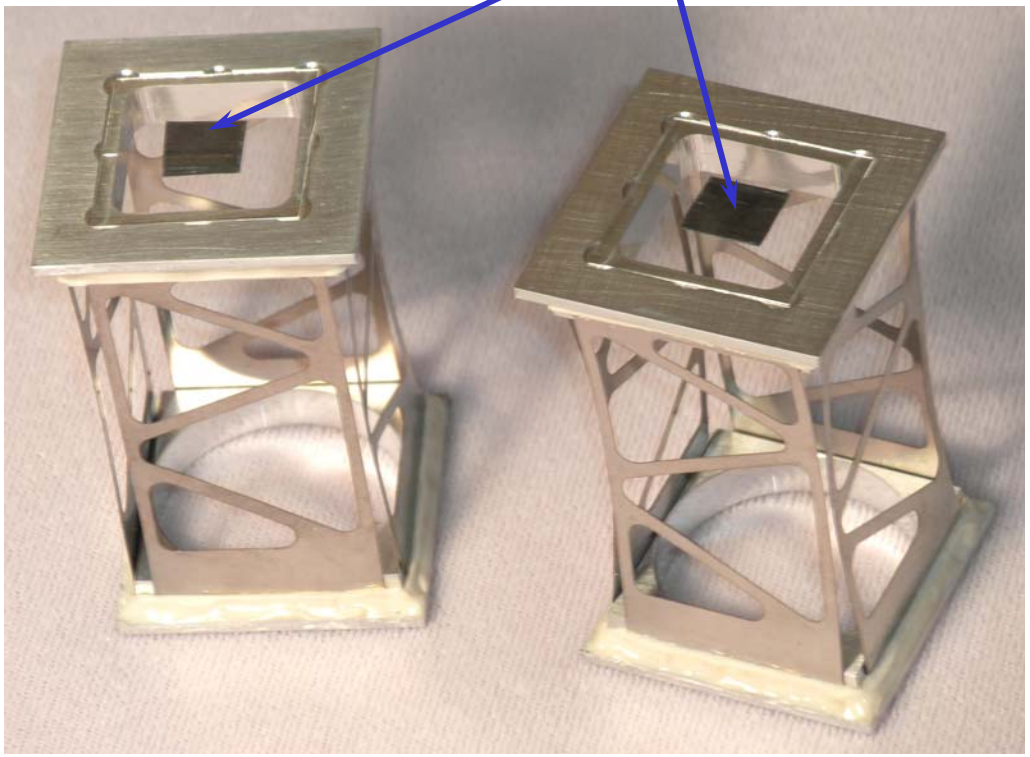
# We are building a calorimeter to measure tape-to-tape process speed



# Calorimeter Prototype Under Construction

- Photographs show thermal isolation stage with tape on top
  - Platform atop truss experiences T rise due to process

Two stages oppose one another to make contact between square samples of tape



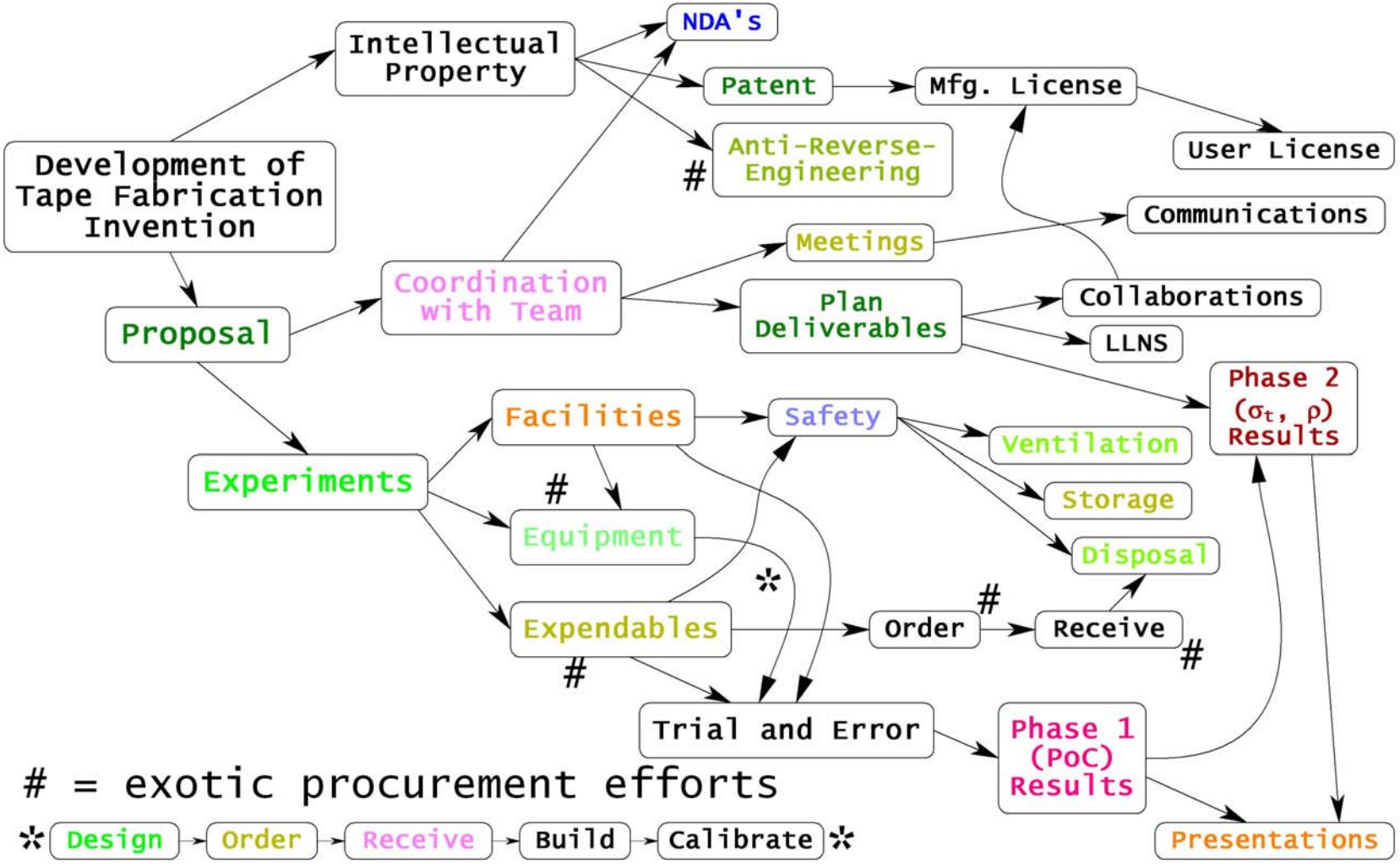
# Collaborations: Partnership with Quantum, Boeing and PNNL explores multiple approaches to reducing vessel cost

- Team members have experience making composites for profit
  - Potential adoption path for LLNL technology
- Not just manufacturers and technology licensees
  - More conventional processes are being developed
  - Direct-but-slower precedent for tape fabrication

- Quantum (Prime): vessel manufacturer & vehicle integrator
- Boeing: Experts in fiber placement
- PNNL: production economics

# Integration of LLNL R+D Activities with Team Plans

## Cartoon Gantt Chart showing LLNL Activities and Team Results

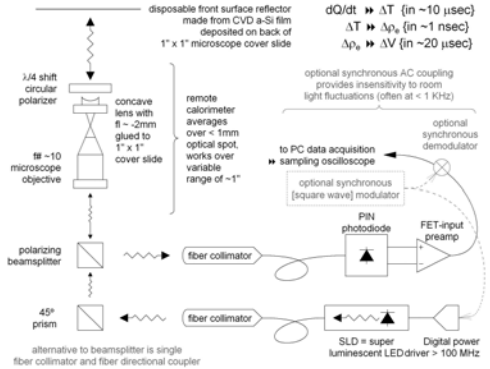


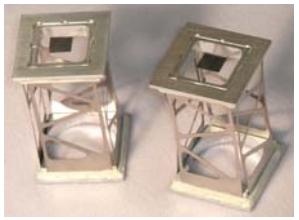

## Note: colors progress from red (unfinished) to green (done)

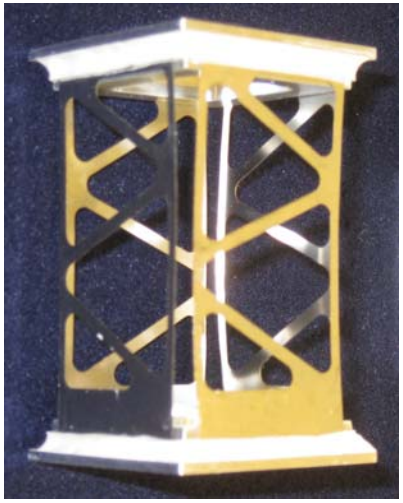
# Future work: in the next two years we will manufacture dry tape and demonstrate its potential for fast winding

- Equipment this adapted to an unprecedented fast process is not commercially available – but the necessary pieces are
- Year 1 version of the requisite Instrument is designed to expand into prototype system capable of 2-axis motion
  - Second axis is actual production geometry of tape process
- Proof of Concept in Year 1 enables strength tests in Year 2
- Capture of preliminary process economics information for inclusion in PNNL model includes process speed, processed tensile strength, final fiber density, and estimated machine cost

# Summary:
# LLNL's dry winding technology has long-term potential for significantly reducing composite vessel cost





**LLNL is conducting Proof of Concept Experiments to demonstrate the feasibility and economic consequences of this innovative manufacturing process**