DOE Hydrogen Program

Inexpensive pressure vessel production through fast dry winding manufacture

Andrew Weisberg, Salvador Aceves, Blake Myers, Tim Ross

Lawrence Livermore National Laboratory

May 20, 2009

Project ID # mfp_01_weisberg

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

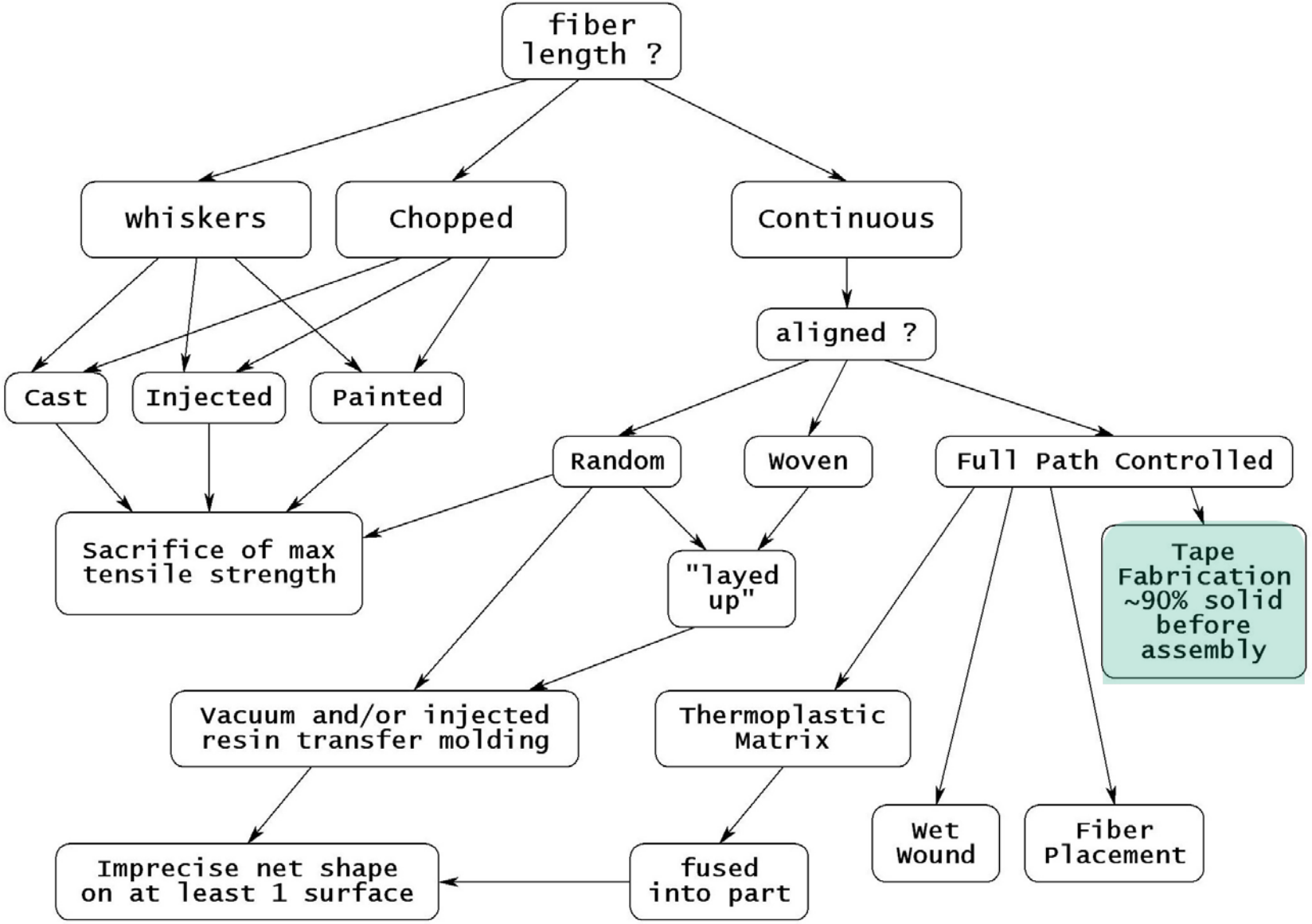
- **What do we mean by tape fabrication ?**



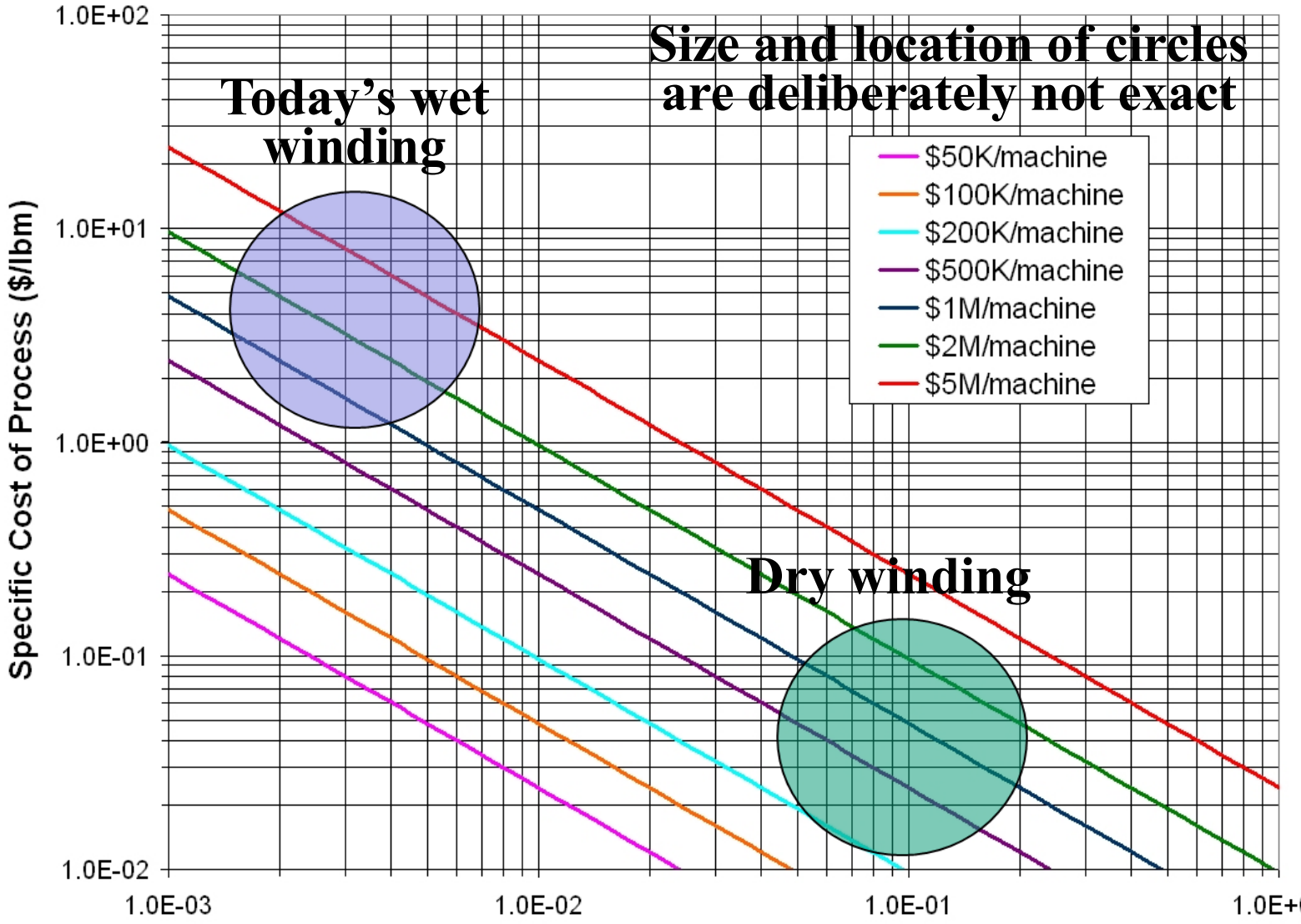


- **Much cannot be shown due to proprietary technology**

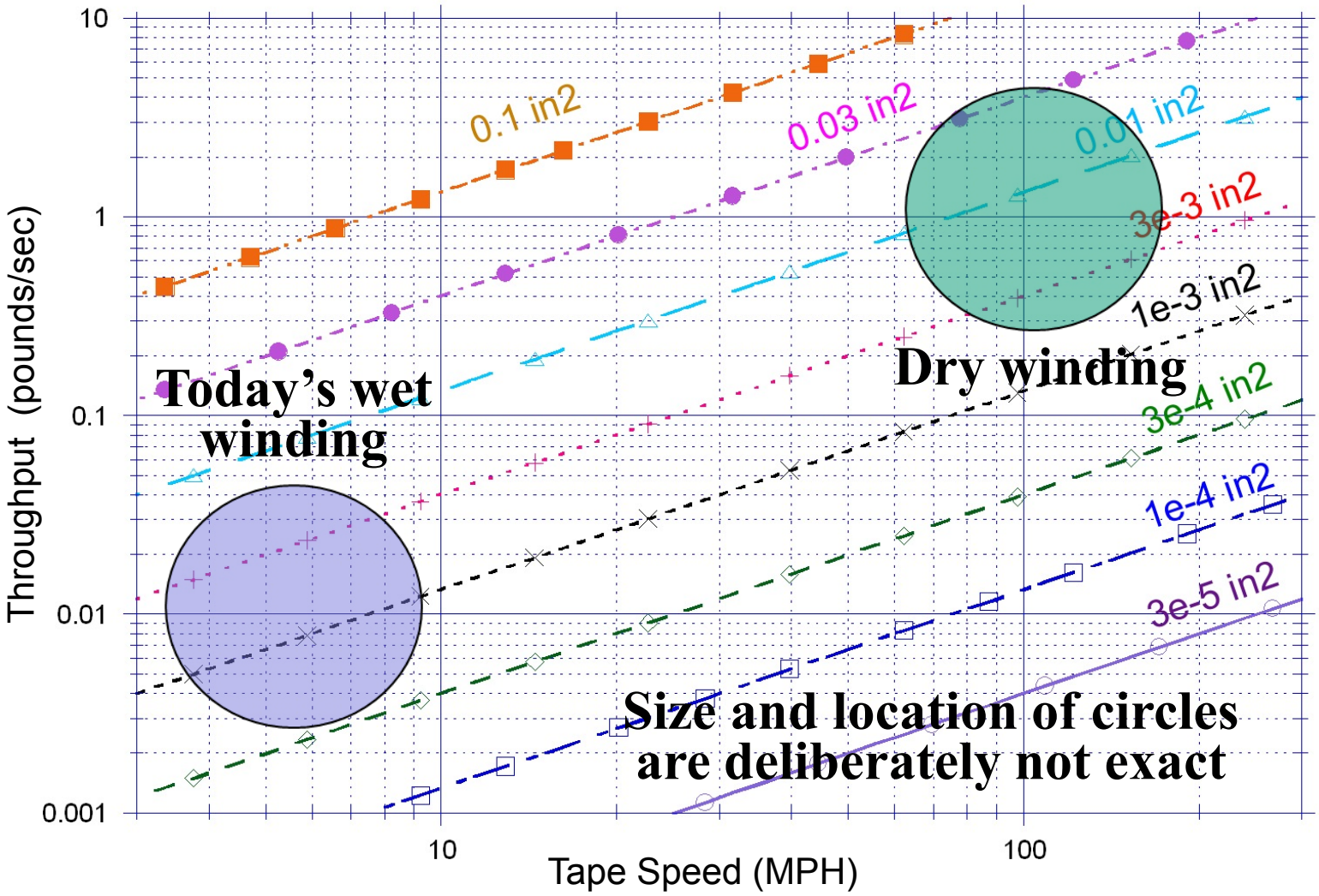
LLNL patent pending tape fabrication technology retains high fiber strength through continuous fiber path control



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

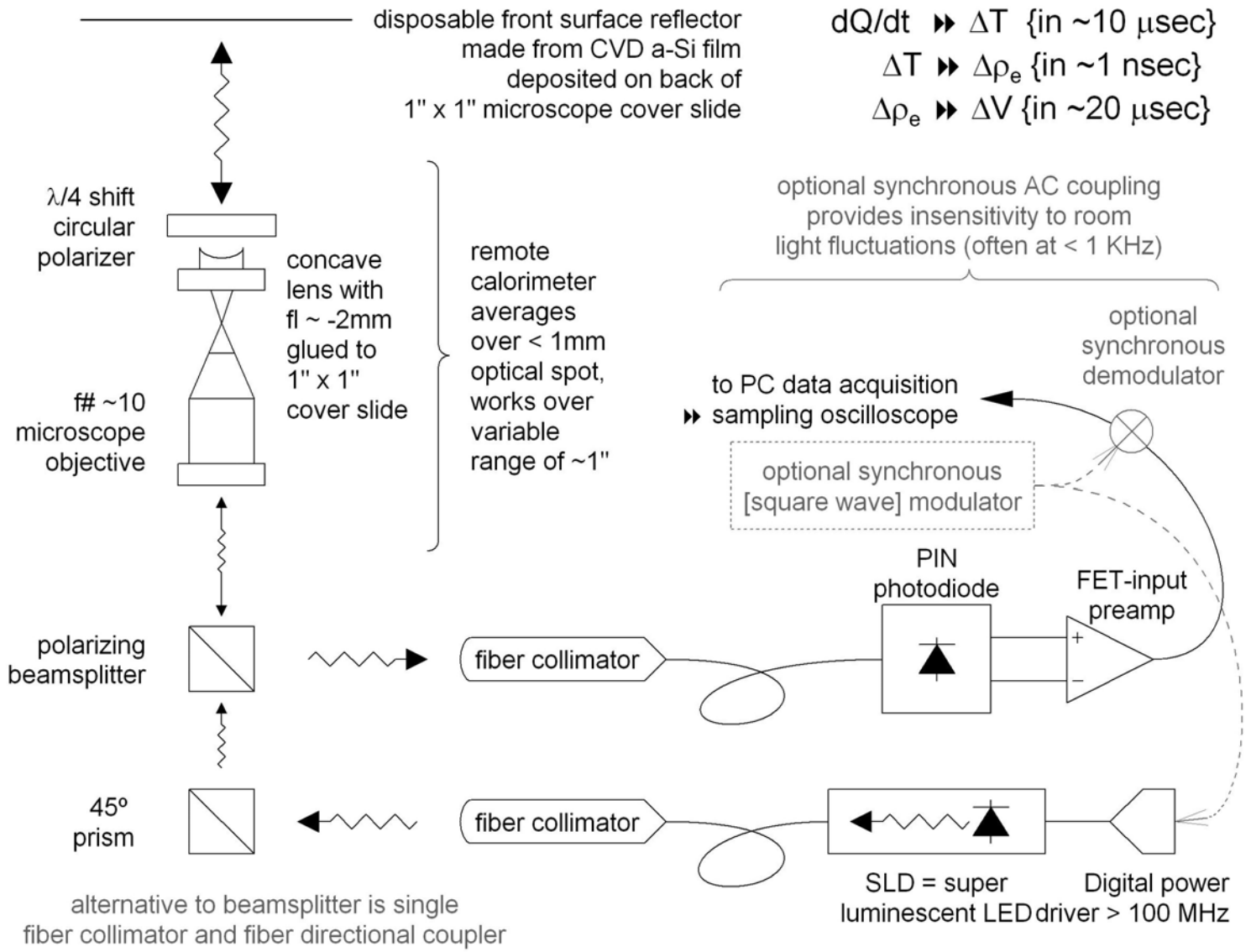
DOCKET: IL-11964

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%

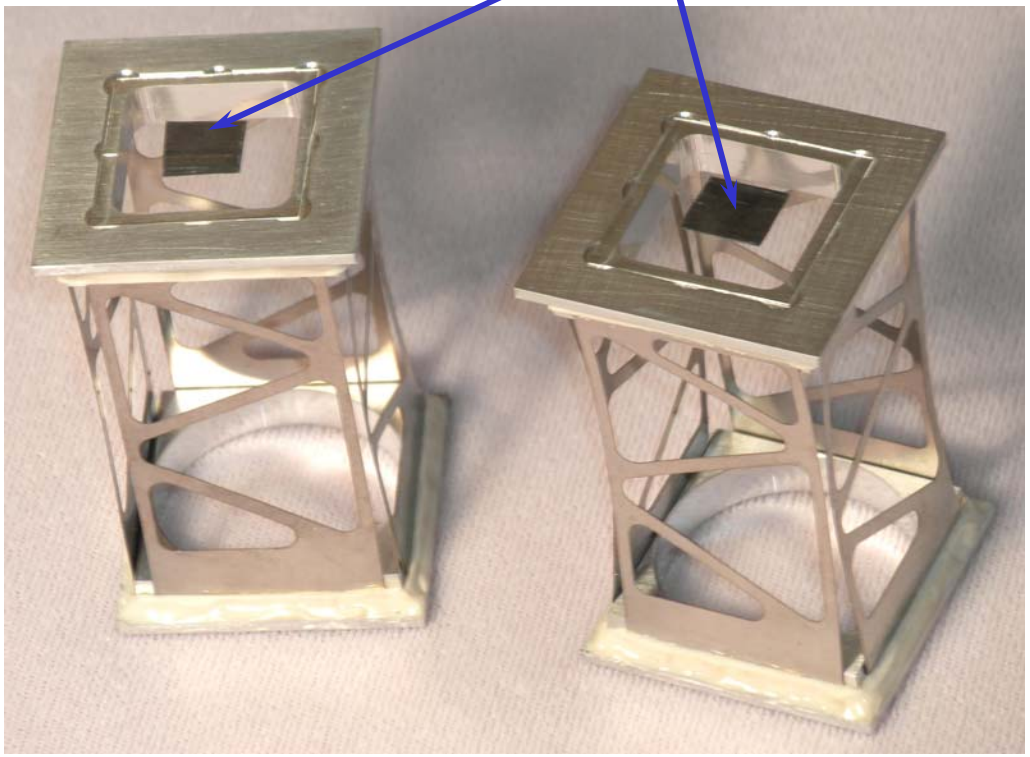
We are building a calorimeter to measure tape-to-tape process speed



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



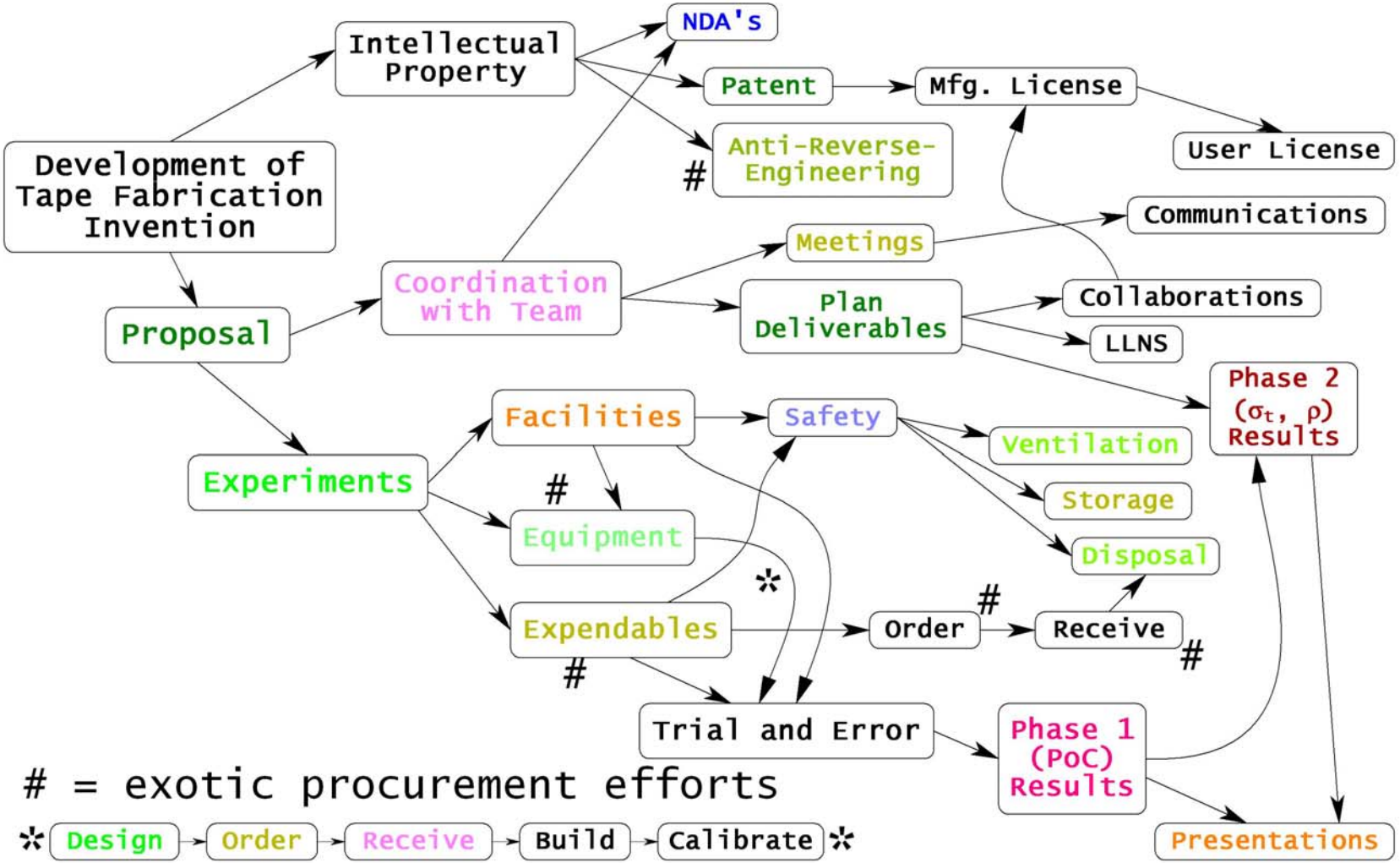
Collaborations: Partnership with Quantum, Boeing and PNNL explores multiple approaches to reducing vessel cost

- 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

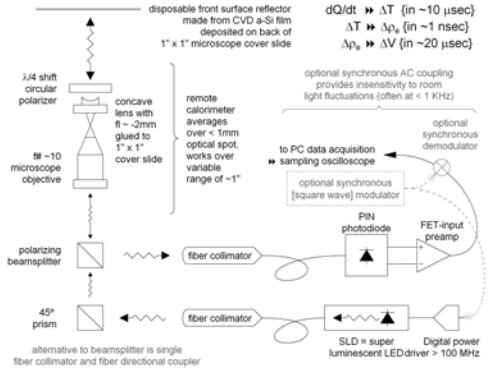


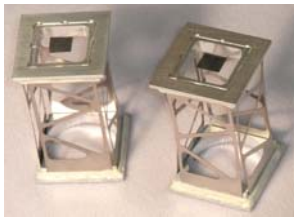
Note: colors progress from red (unfinished) to green (done)

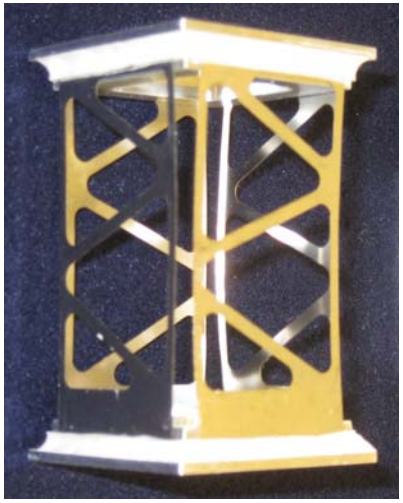
Future work: in the next two years we will manufacture dry tape and demonstrate its potential for fast winding

- 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