GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2014

Georgia Tech MENTOR2 CREATE

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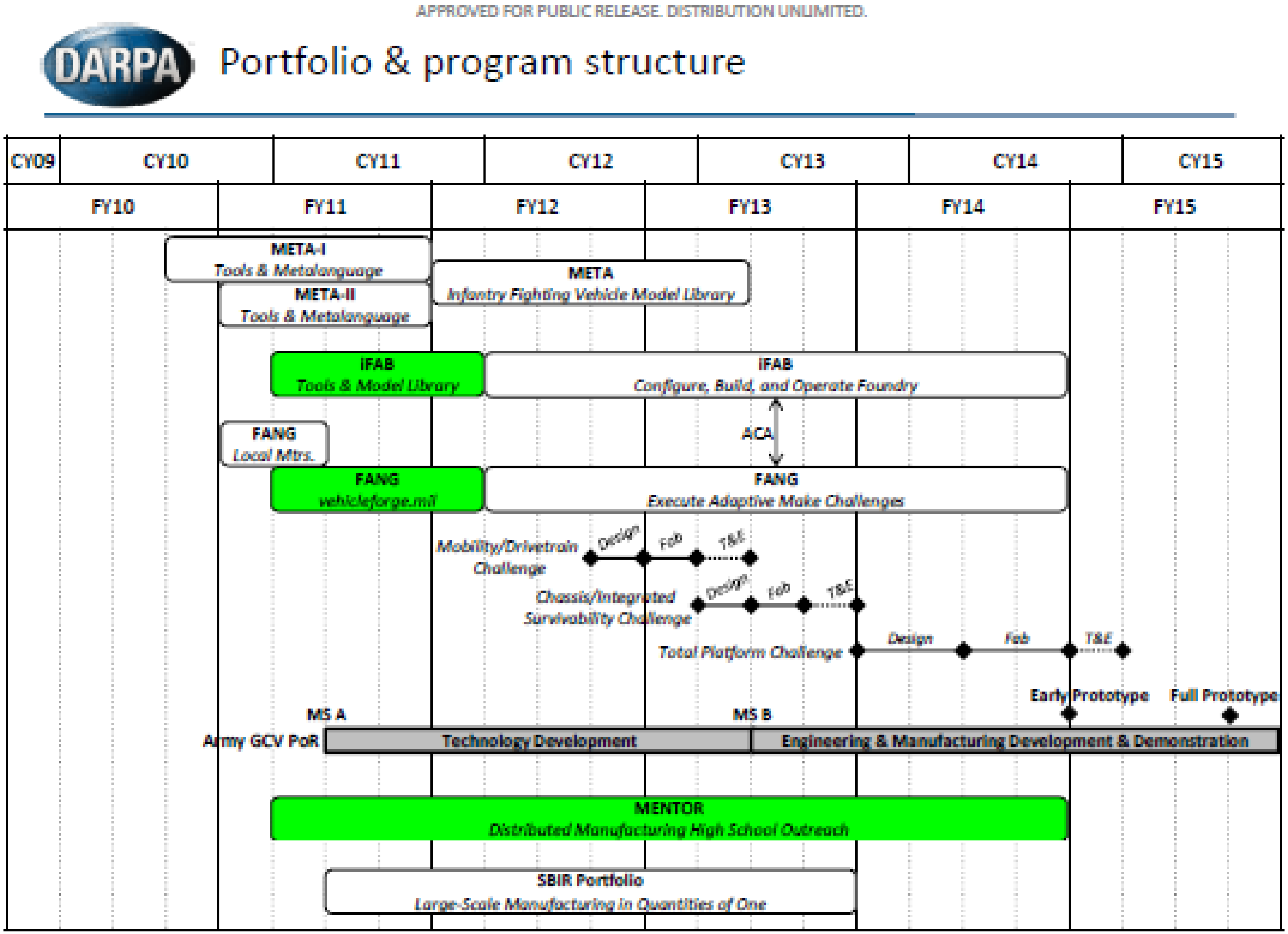
Presentation Outline

- Overview of Proposed MENTOR2 CREATE
- Providing an Integrated Product Lifecycle Engineering (IPLE) Approach for Incorporating *Model Based Engineering (MBE)* and a *Digital Thread* Centerpiece for Exercising Product Lifecycle Functions: *Co-Create*, *Design*, *Build* & *Operate* (CDBO) followed by *Diagnose*, *Repair* & *Adapt*
- Proposed Objectives for MENTOR2 CREATE for *Diagnosing*, *Repairing* and *Adapting* the *Understood* Complex Electro-mechanical systems for both Secondary and Post-Secondary Education
- Example for *Understanding* complex electro-mechanical systems at the Secondary Education Level
- Example for *Diagnosing*, *Repairing* and *Adapting* a Quad Rotor for different missions at the Post Secondary Level

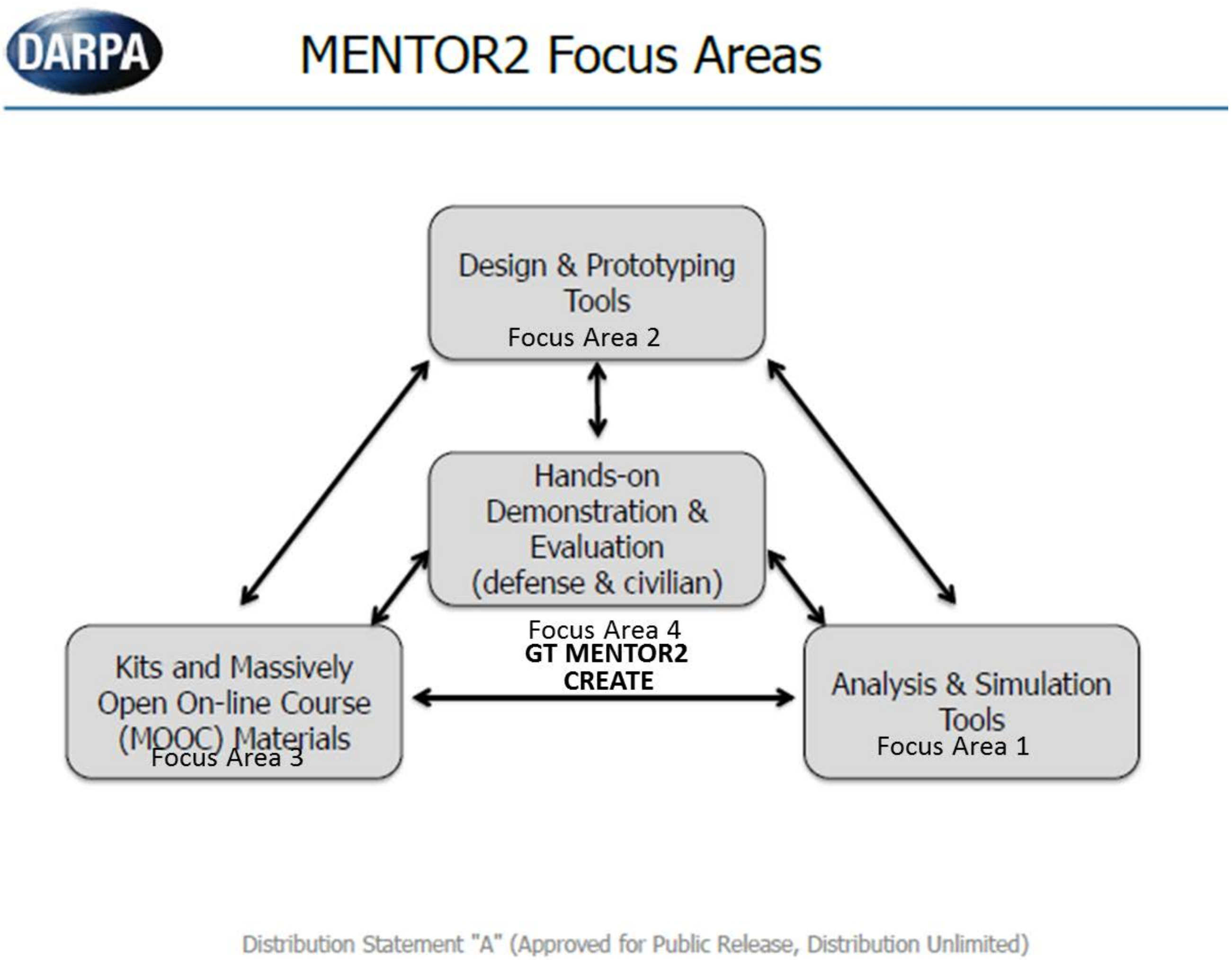
Overview of MENTOR2 CREATE

- The DARPA DSO Manufacturing ExperimeNTation OutReach (MENTOR)2 is the second DARPA MENTOR Program; the first MENTOR was the outreach element for the DARPA TTO Adaptive Vehicle Make (AVM) Program
- The Georgia Tech MENTOR2 Collaborative Repository for Engineering And TEchnology (CREATE) project enables students, hobbyists and military personnel to *understand*, *diagnose*, *repair* and *adapt* high technology electro-mechanical systems that are often used in isolated or challenging environments, e.g. austere environments
- MENTOR2 includes Four Focus Areas with three other contractors in addition to Georgia Tech who leads the Demonstration and Evaluation Focus Area

First MENTOR Intended as the AVM Outreach Program; However, terminated after first year



DARPA MENTOR2 Four Focus Areas wih Georgia Tech (GT) leading Focus Area 4



DARPA MENTOR2 Focus Areas

Focus Area 1: Analysis and Simulation Tools

- Allow student and instructor to determine the operation of individual components, the linkages between components, and the properties of components and sub-components that optimize the overall performance of a complex electro-mechanical system. Tools must allow for:
  - Analysis of electrical/mechanical/environmental requirements imposed on a component thus enabling the determination of potential problems, synthesize solutions, customize systems, or re-design components to improve operational readiness
  - Analysis of critical electrical, mechanical and environmental parameters of a component to allow for in-field manufacturing of parts
- Build upon open-source simulation systems "Gazebo" and "Cloudsim" developed by the Open Source Robotics Foundation, and develop further open-source, real-time, human-interactive simulation tools to add to those systems.

1

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

DARPA MENTOR2 Focus Areas

Focus Area 2: Design and Prototyping Tools

- Build upon recently developed design tools and low-cost rapid prototyping innovations
- Develop or expand open-source lower cost, Computer Numerical Control (CNC) rapid prototyping tools for use in instructional and in-field environments

While additive manufacturing tools are acceptable, proposers should consider the entire range of tools (e.g., additive, subtractive, casting, automated assembly, etc....).

MENTOR2 Focus Areas

Focus Area 3: Project Kits and Massively Open On-line Course (MOOC) Materials

- Build on existing, widely used, delivery MOOC substrate and directly link to the MENTOR2 experimental projects and Design/Simulation Tools.
- Develop open-source experimental kits
  - small number of exemplary projects that provide materials and guidance
  - allow for individual creative freedom and diverse talents to be exploited in the design and construction of authentic problem-based projects
- Develop projects whose performance results in organic, objective, authentic assessment of a student's technical competence and teamwork skills.

DARPA MENTOR2 Focus Areas

Focus Area 4: Evaluation

- Develop a demonstration and test plan that allows for the evaluation of the methods, tools and materials being developed in Focus Areas 1, 2, and 3.
  - It is anticipated that these evaluations will take place at months 6, 12, 18, and 24 of the program.
- Performers should plan for their MENTOR2 tools to be demonstrated at months 12, 18, and 24 at a defense training facility and/or a civilian training facility (e.g., vocational technical school) and/or a non-traditional learning environment (e.g., a Makerspace).
  - Preference will be given to proposals that can be successfully demonstrated at all three types of facility.

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

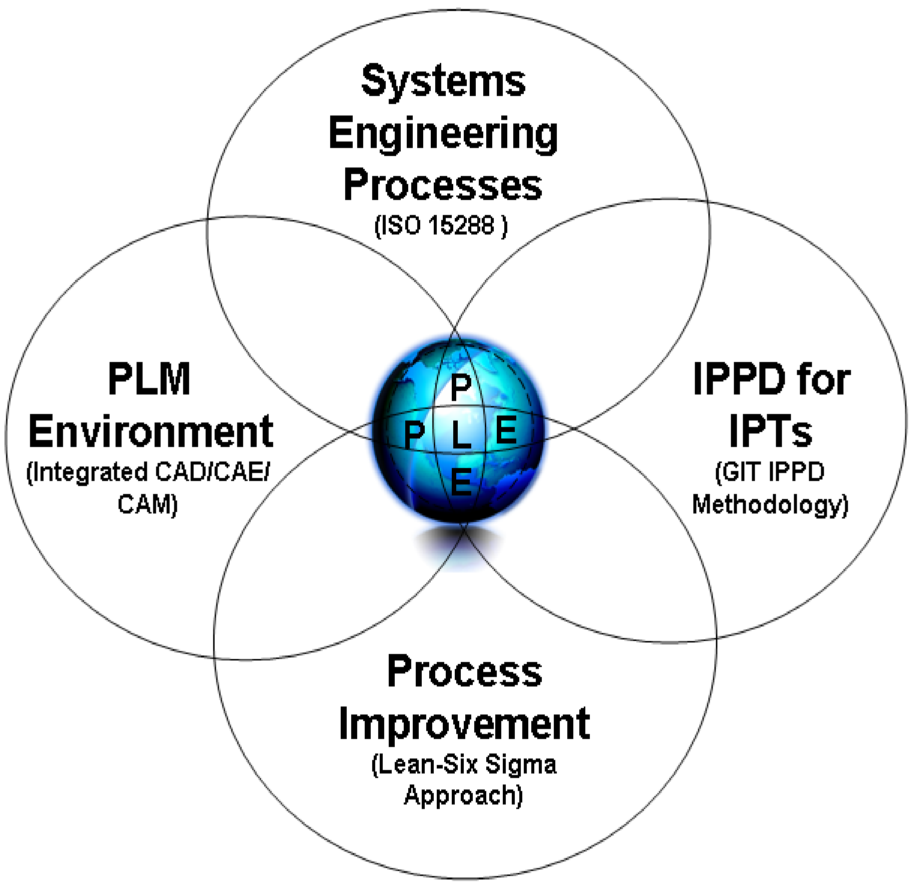
MENTOR2 Can Serve as aTestbed for Emerging Product Data interoperabilityTechnologies

- **Integrated Product Lifecycle Engineering (IPLE)**[1] integrates Four Key Elements: SE, IPPD, QE, & PLM
- **Model Based Engineering (MBE)**[2] is an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability for a system, and/or product throughout the acquisition life cycle
- A **DigitalThread**[3] integrates and drives modern design, manufacturing and product support processes which can be exploited to reduce cycle time and achieve first pass success, and is the only feasible way to deal with the complexity of today's products

[1]Schrage, D. "Product Lifecycle Engineering-An Application", World Encyclopedia for Aerospace Engineering", 2011
[2]Final Report of the MBE Sub-Committee, NDIA Systems Engineering Division, M&S Committee, 2011
[3]http://www.manufacturing.gov/docs/DMDI_overview.pdf

An Integrated Product Lifecycle Engineering(IPLE)Approach

Product Lifecycle Engineering (PLE) is at the Intersection of Four Overlapping Processes

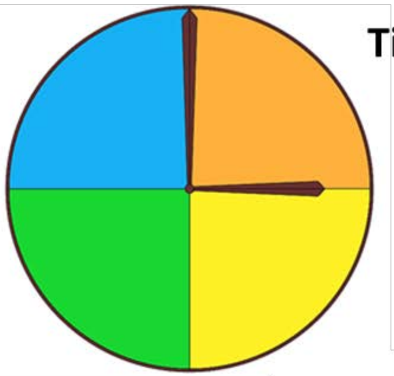


Proposed Objectives for GT MENTOR2 CREATE

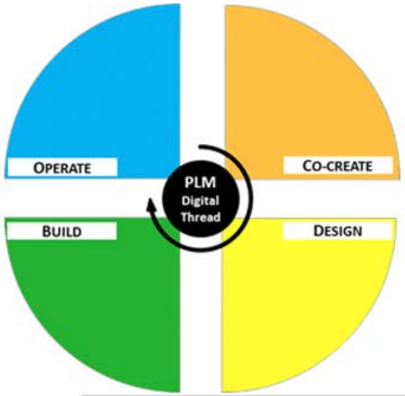
1.) CREATE enables users of all skill levels to perform tasks throughout the entire lifecycle (design, manufacturing, and support) for electro-mechanical systems. This includes providing an initial *Co-Create*, *Design*, *Build* and *Operate* (CDBO) iteration for *understanding* the baseline electro-mechanical systems; followed by a second iteration for *diagnosing* required modifications from *repairing* malfunctions to *adapting* components to reflect operational needs.

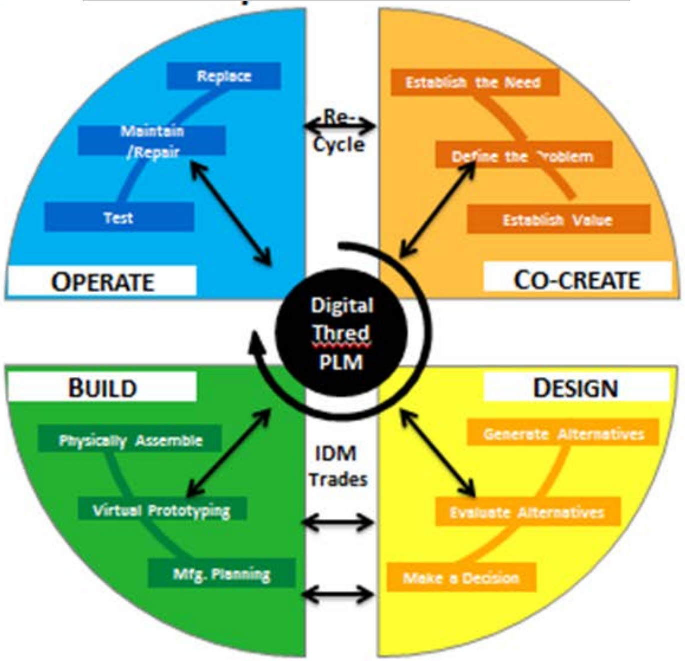
2.) Using *Analysis and Simulation* Tools from Focus Area 1, *Design and Prototyping* Tools from Focus Area 2, and *Project Kits and MOOCs* from Focus Area 3, CREATE will conduct Focus Area 4 *Demonstrations and Evaluations* of student teams. This will provide iterative feedback to guide the MENTOR2 team on how to improve education for *diagnosing*, *repairing* and *adapting* high technology systems in low technology, austere environments.

A Time-based Approach for the PLE Functions of Co-Create, Design, Build and Operate (CDBO) with a Digital Thread for Understanding

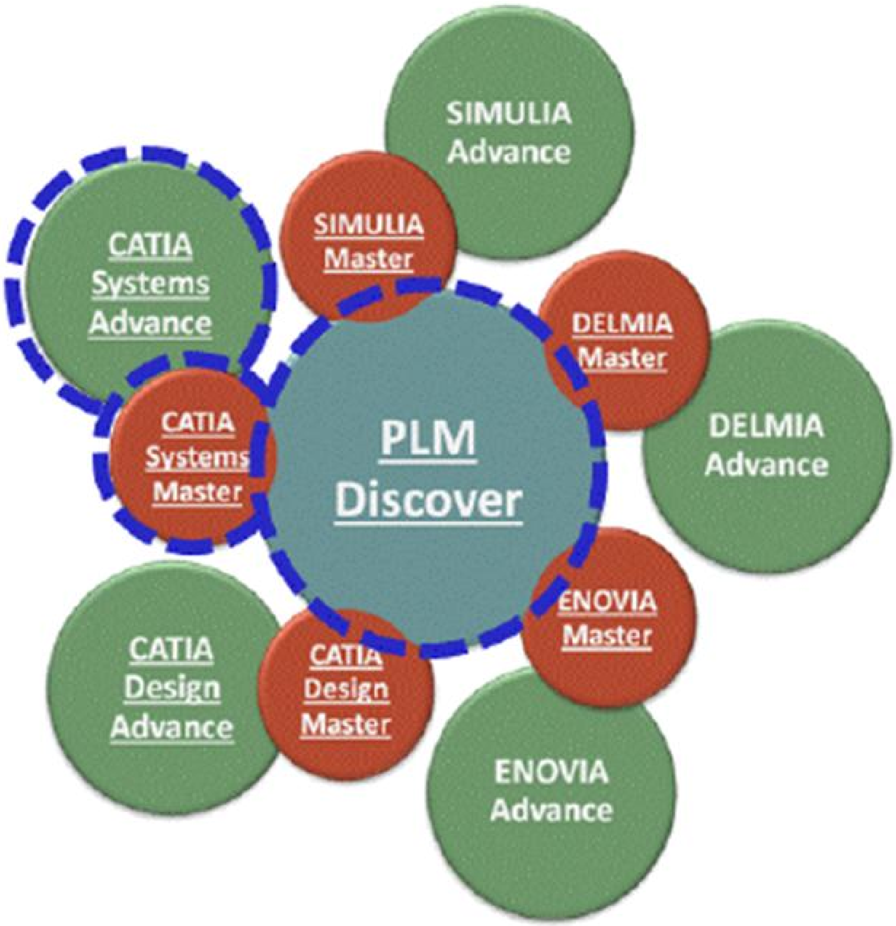


Time-based + PLE Functions
+
Digital Thread for PLM
+
IPPD Methods & Tools
= CDBO Approach

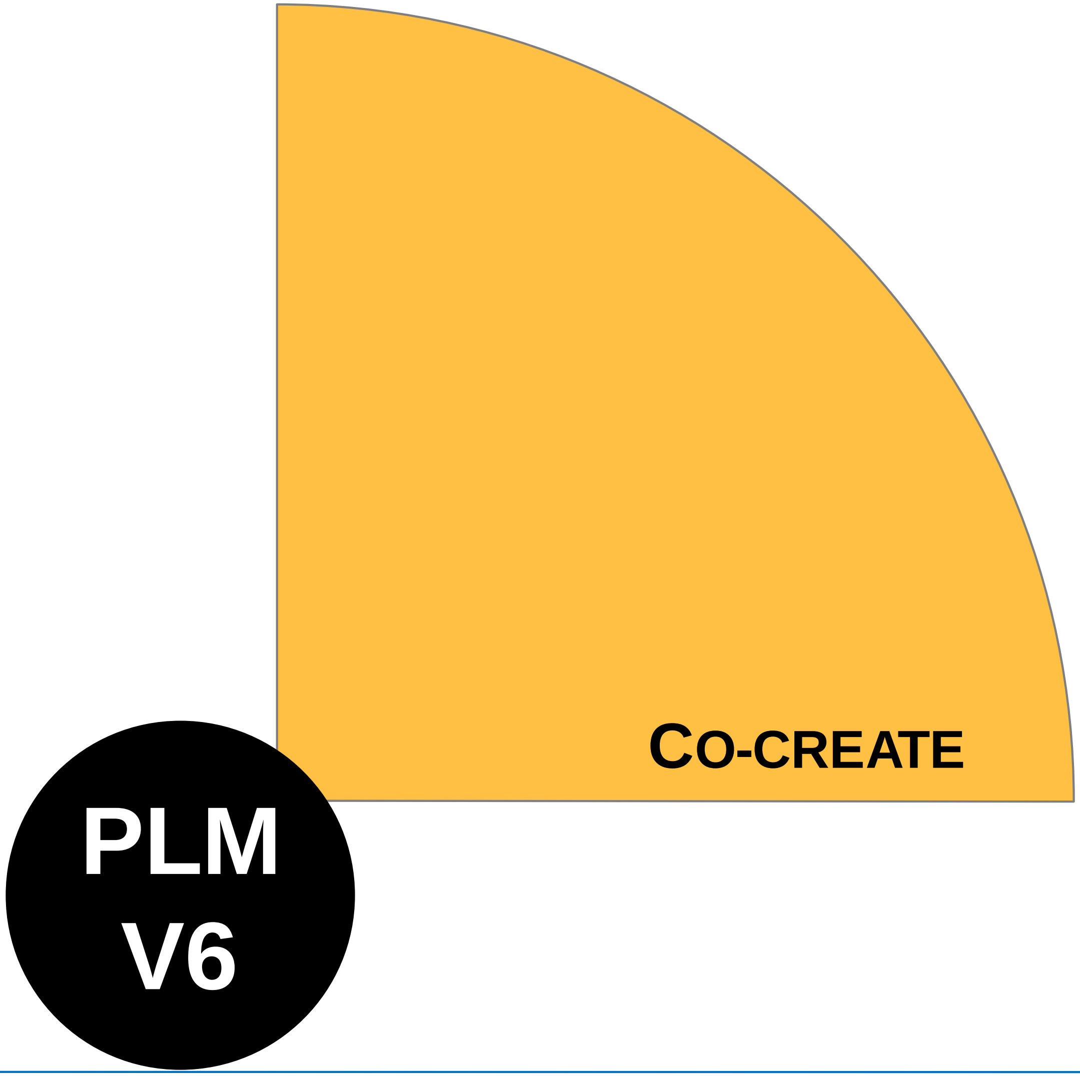




Dassault Systemes PLM V6 Discover as a Digital Thread for Integrating MBE Educational Tools

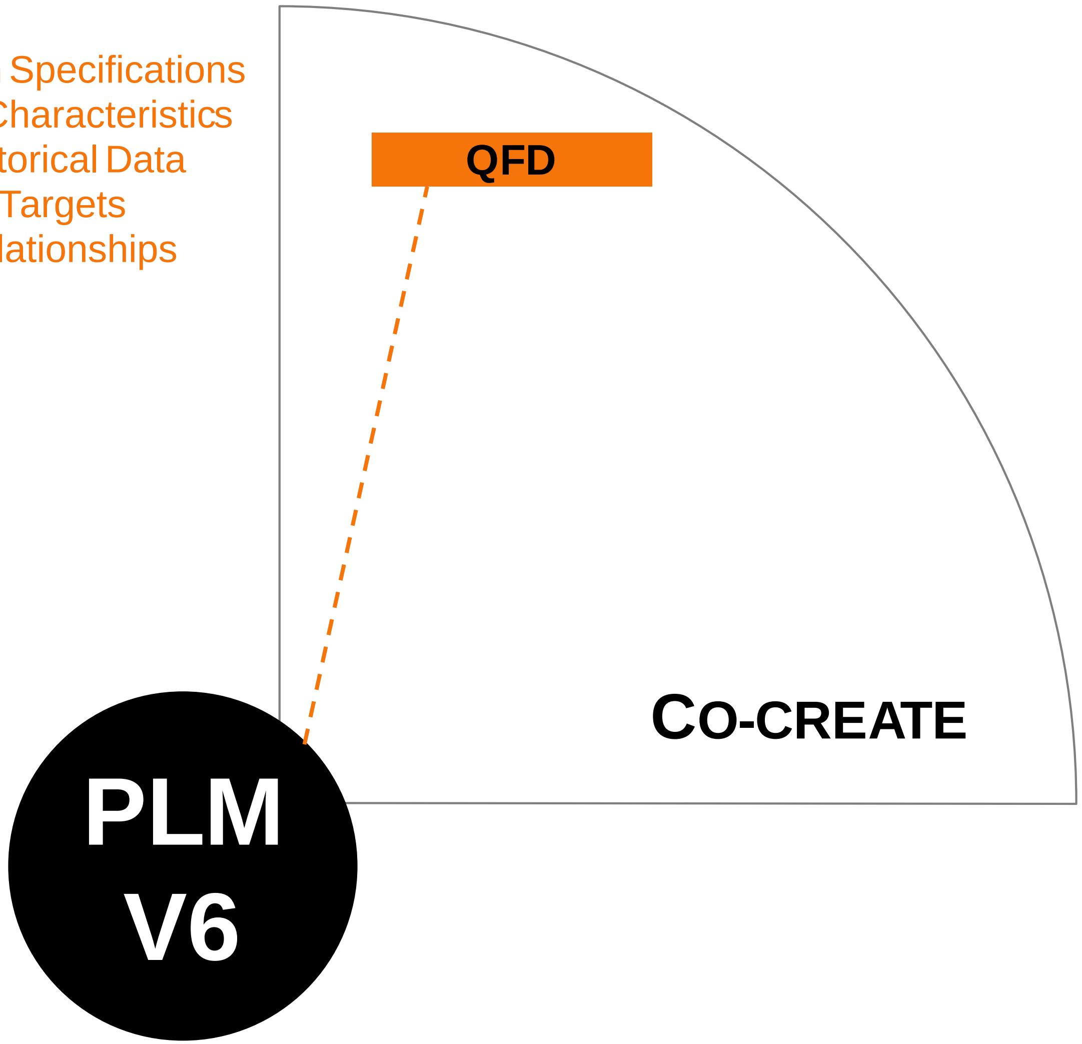


First Step is to Co-Create with Distributed Team Members

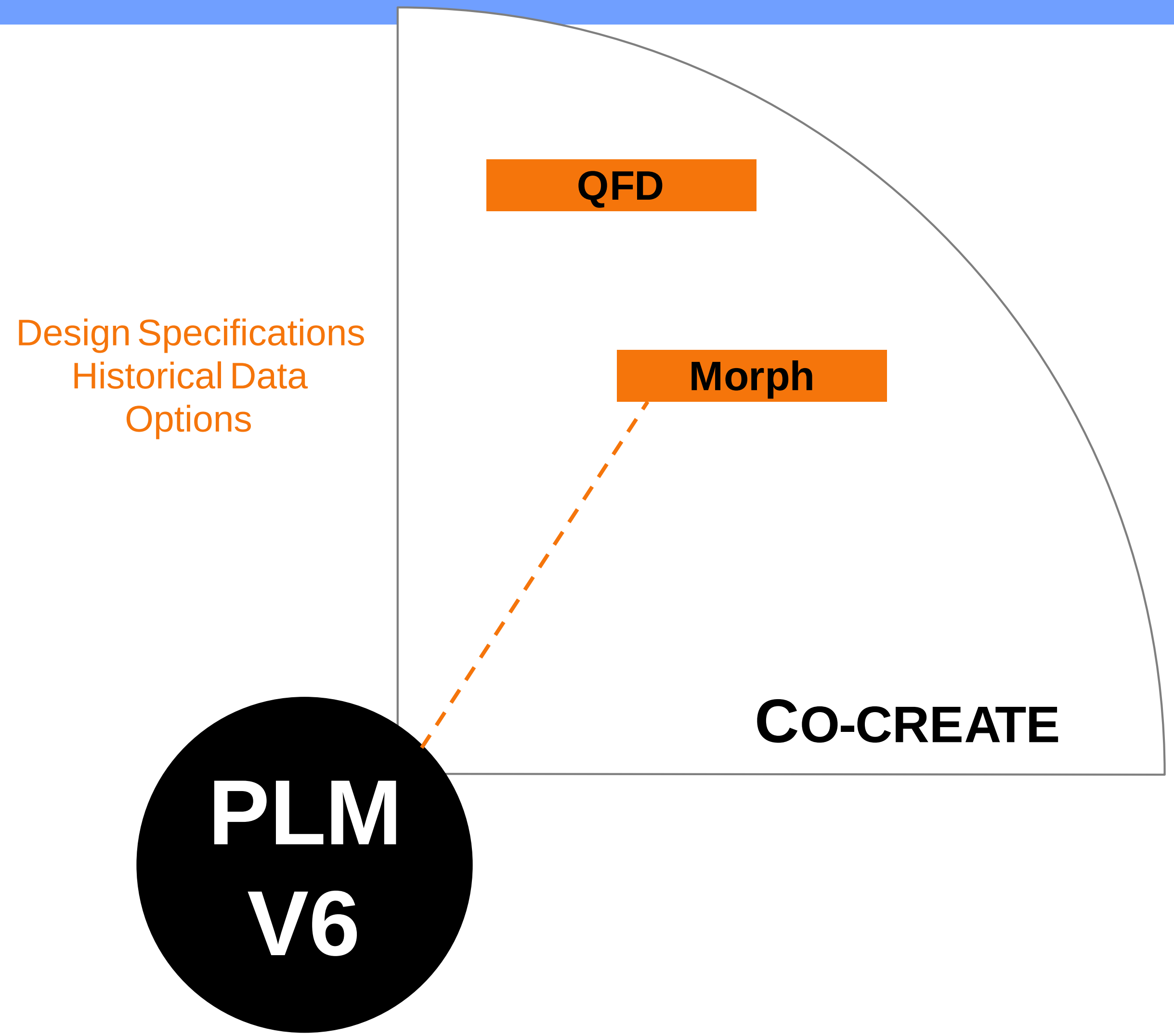


QFD translates Voice of the Customer into Key Product and Process Characteristics

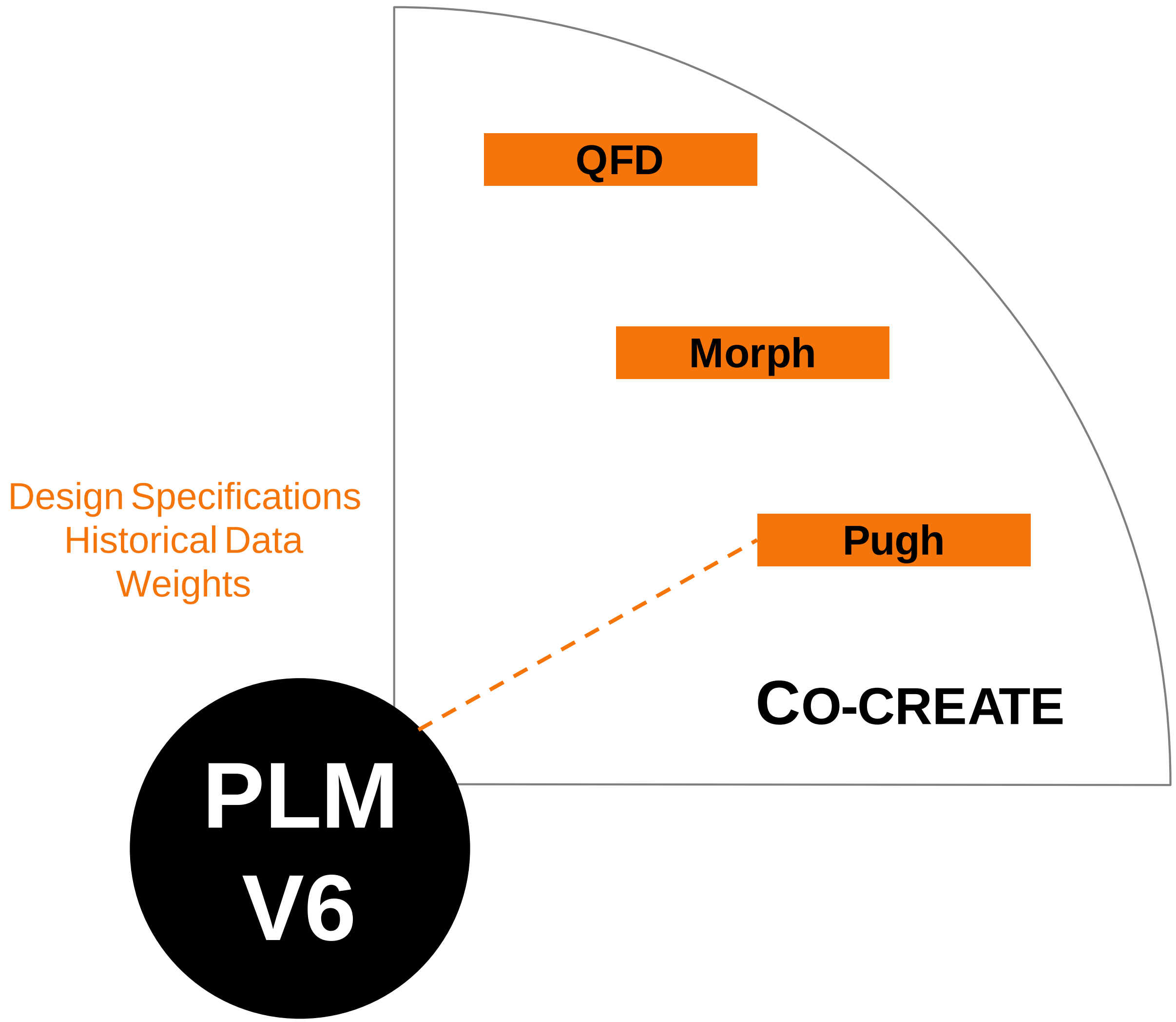
Design Specifications
Eng. Characteristics
Historical Data
Targets
Relationships



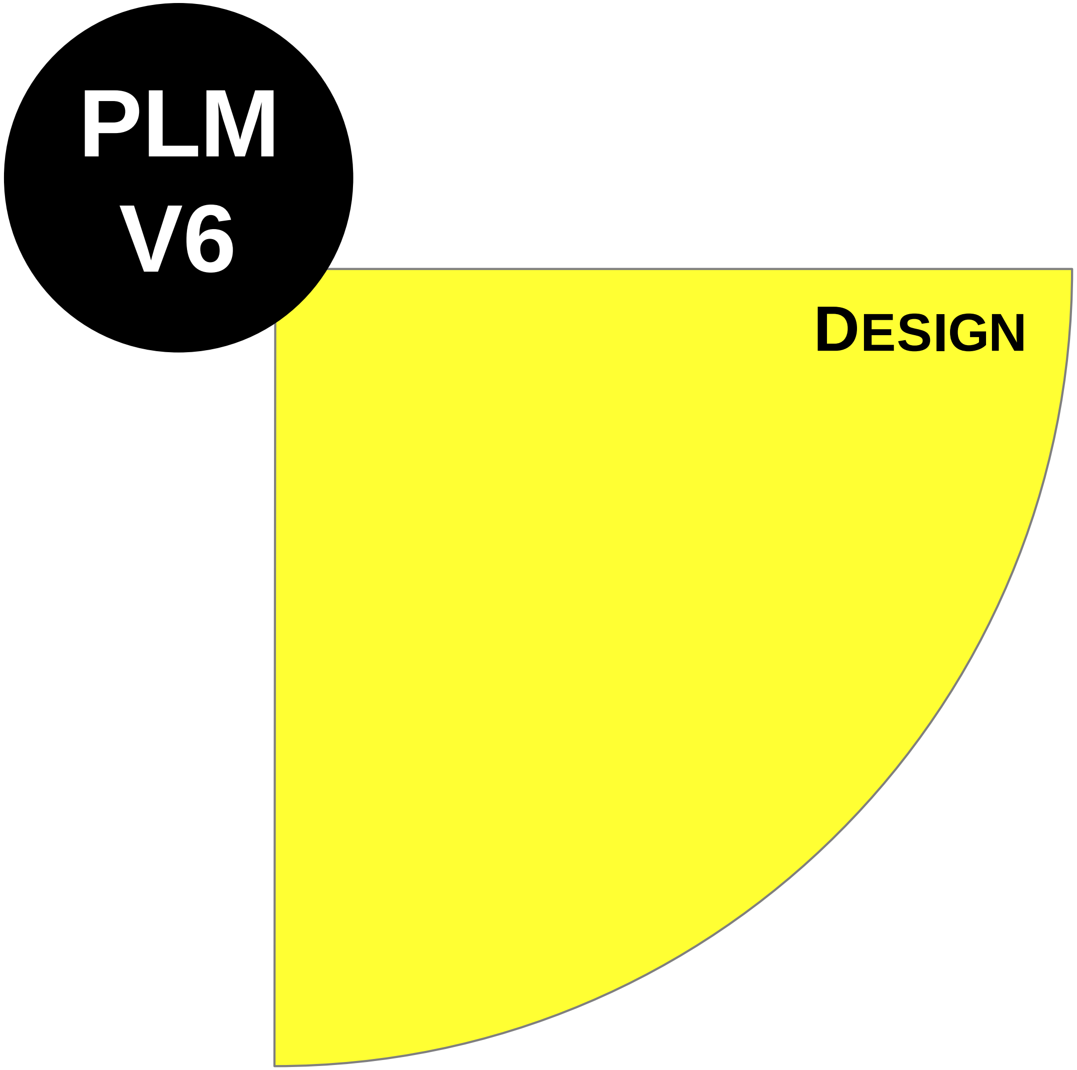
Morphological Matrices Provide Creative Way to identify Innovative Solutions



Pugh Concept Evaluation Method Provides visual way for Subjective Evaluation of Alternatives

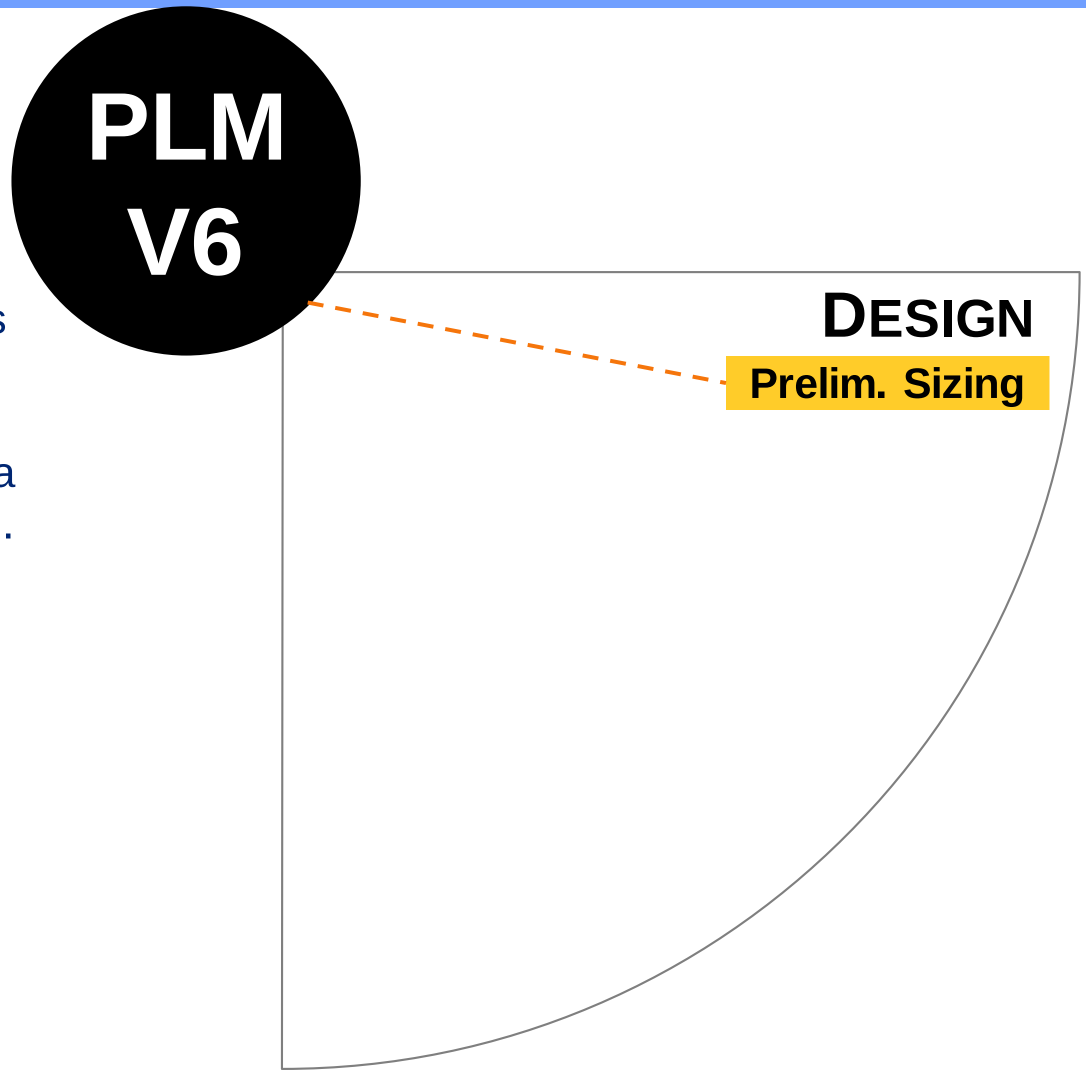


Next Step is to turn Concept Selection into a Preliminary Design



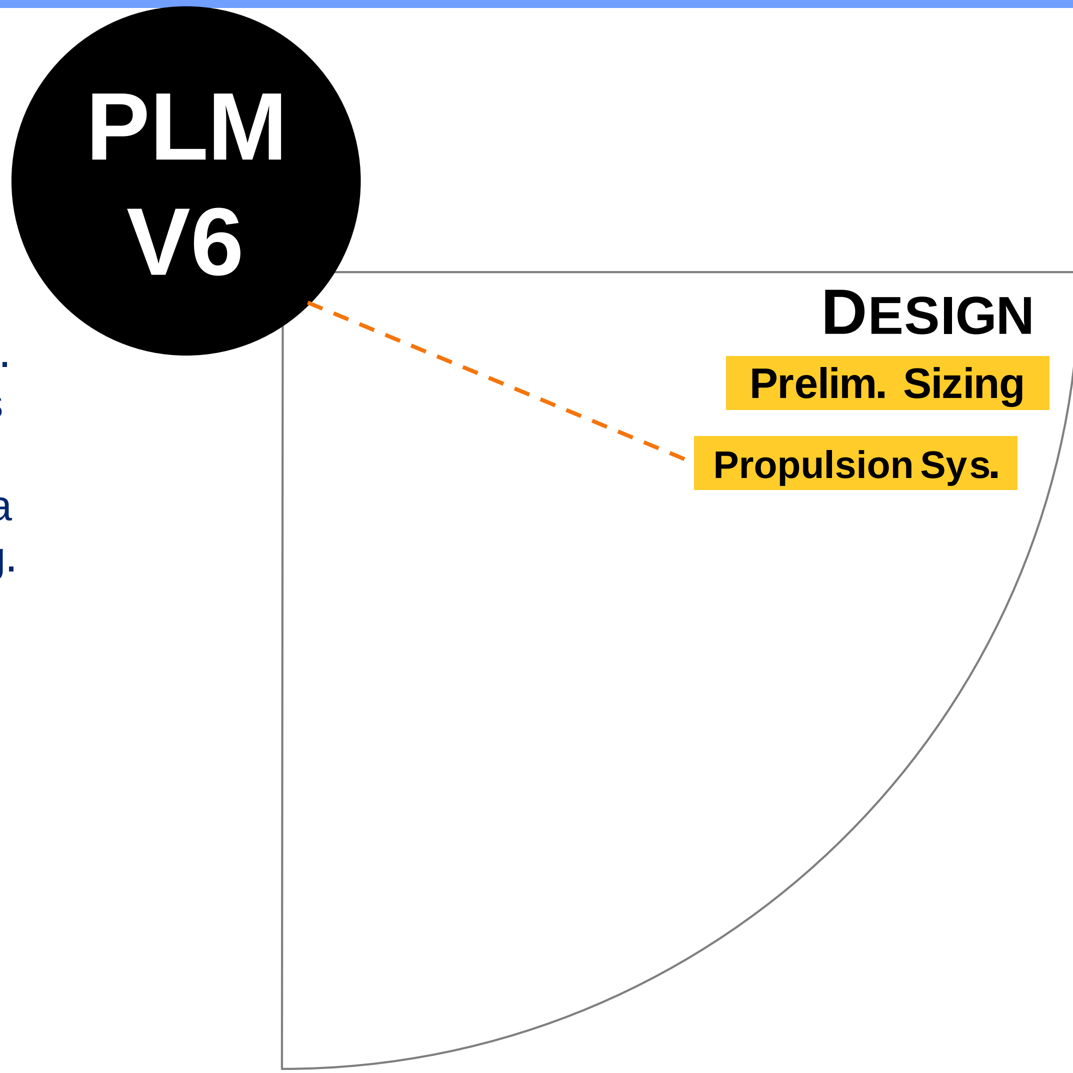
Preliminary Sizing kicks off Preliminary Design

Load Targets
Trade Studies
CATIA/CAD
Simulation
Historical Data
Prelim. Config.

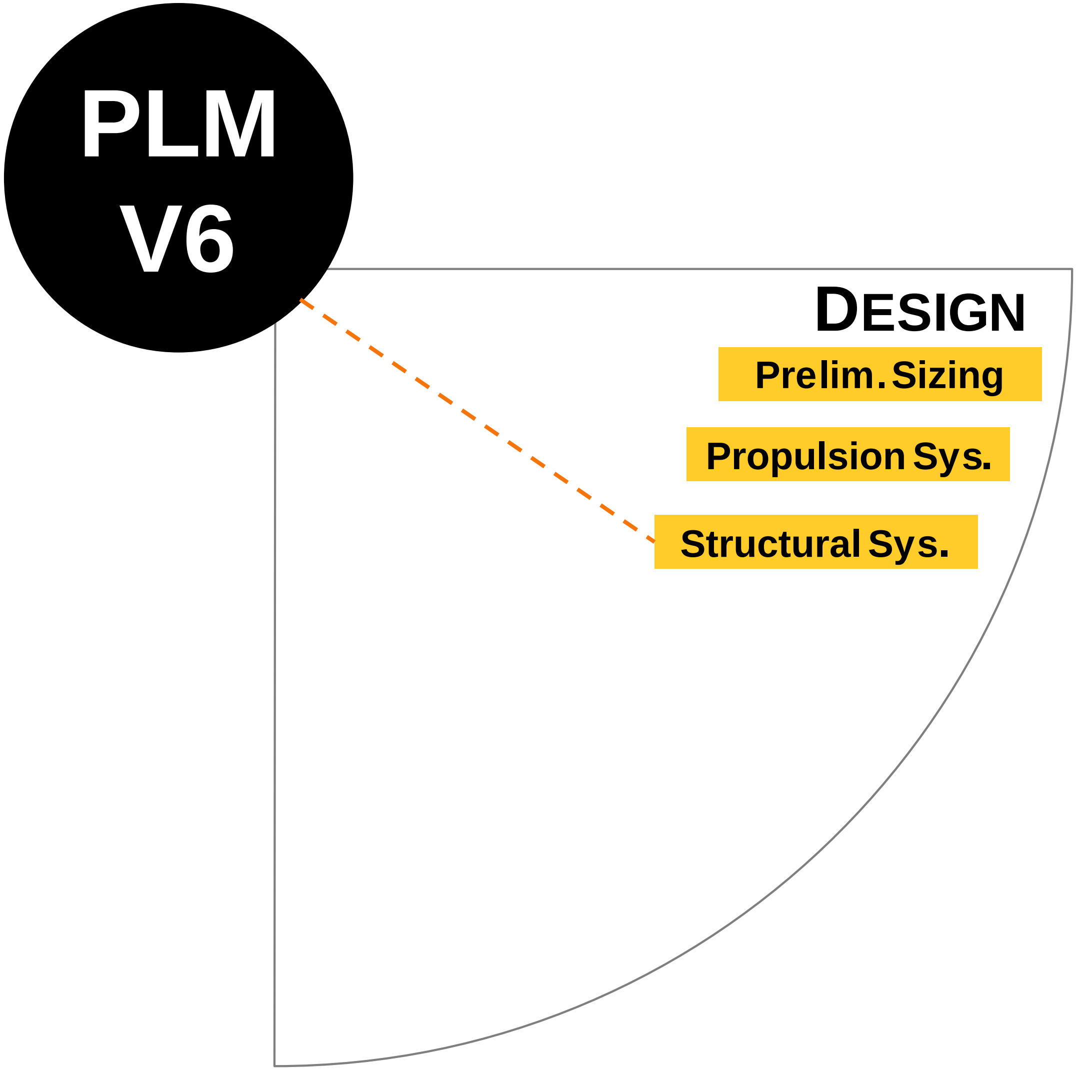


Propulsion System Design is the Next Step

Prelim. Config.
Trade Studies
Simulation
Historical Data
Refined Config.

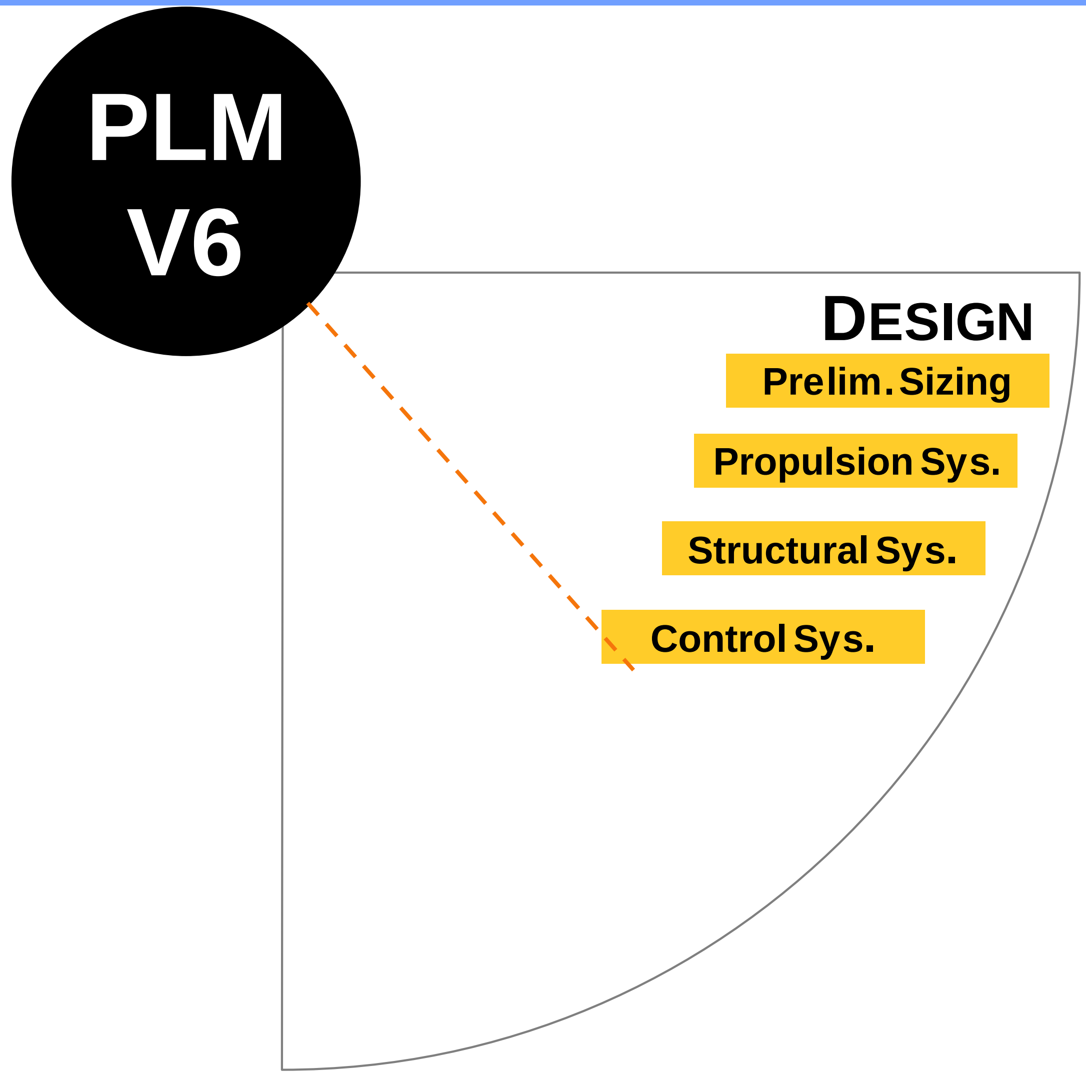


Structural System Design Follows



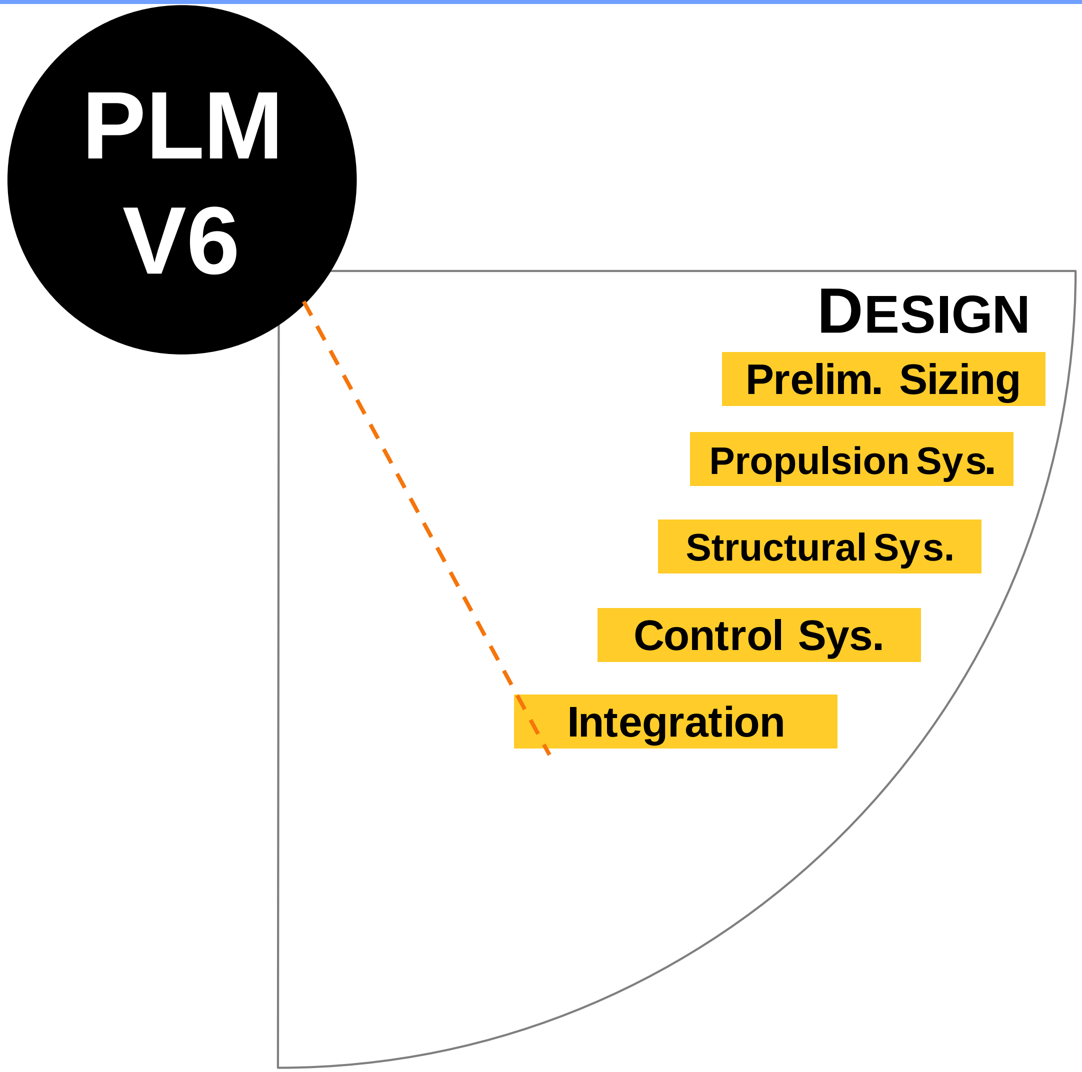
Prelim. Config.
CATIA/CAD
SIMULIA/FEA
Testing
Historical Data
Refined Config.

Control System Design is the Critical Next Step



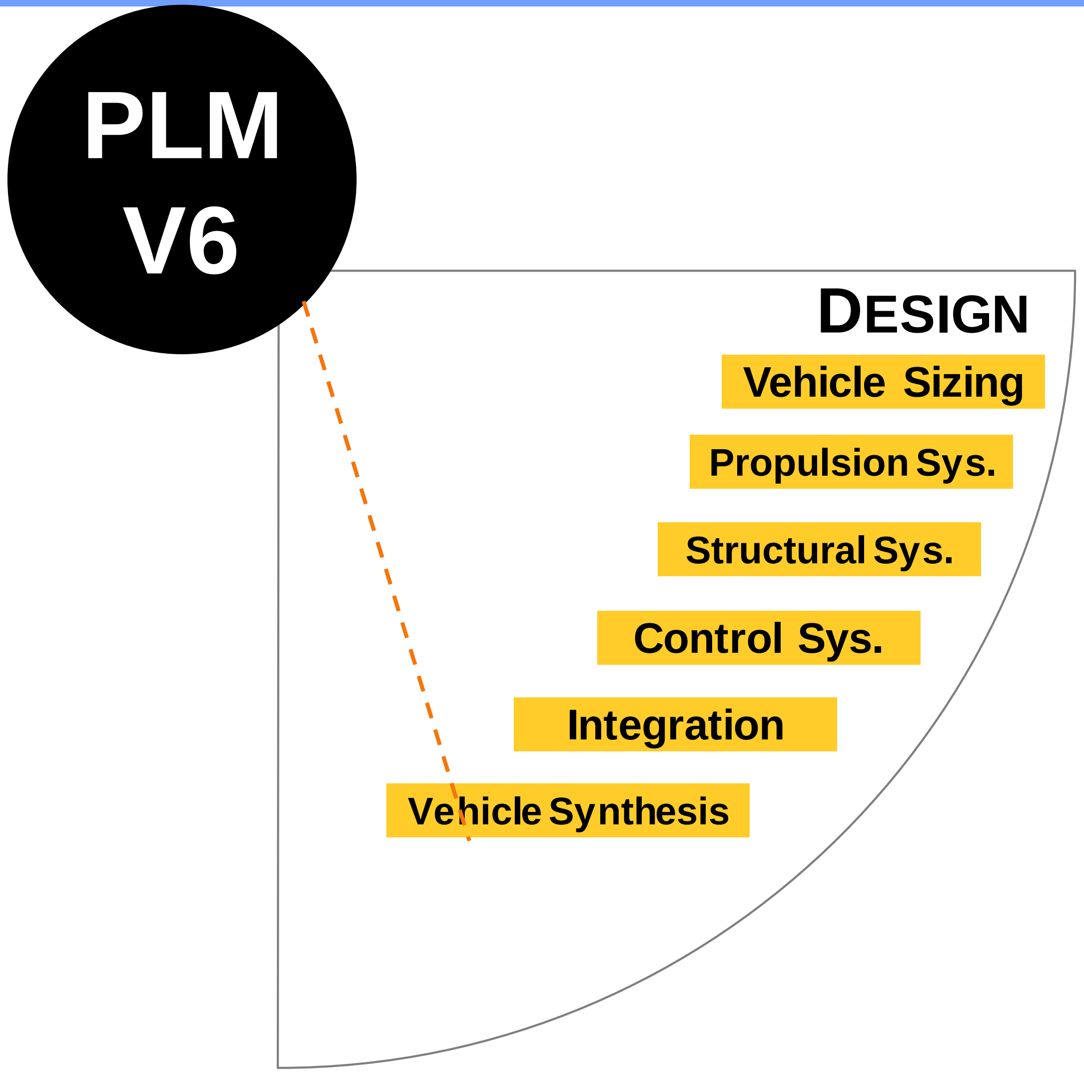
Prelim. Config.
CATIA/CAD
Simulation
Historical Data
Refined Config.

Integration is Next Critical Step



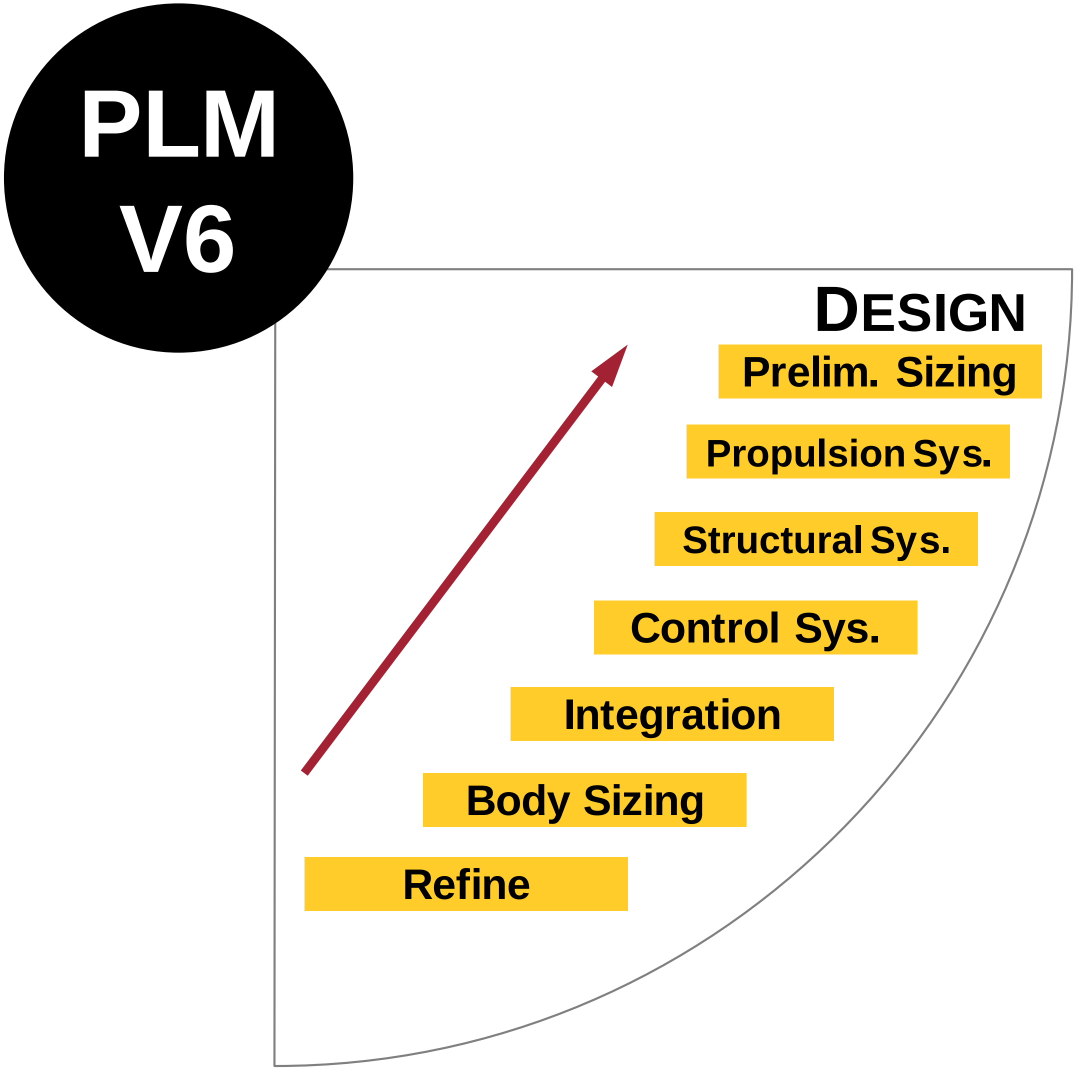
Load Systems
CATIA/CAD
Refined Config.

Vehicle Synthesis Brings the Design Together

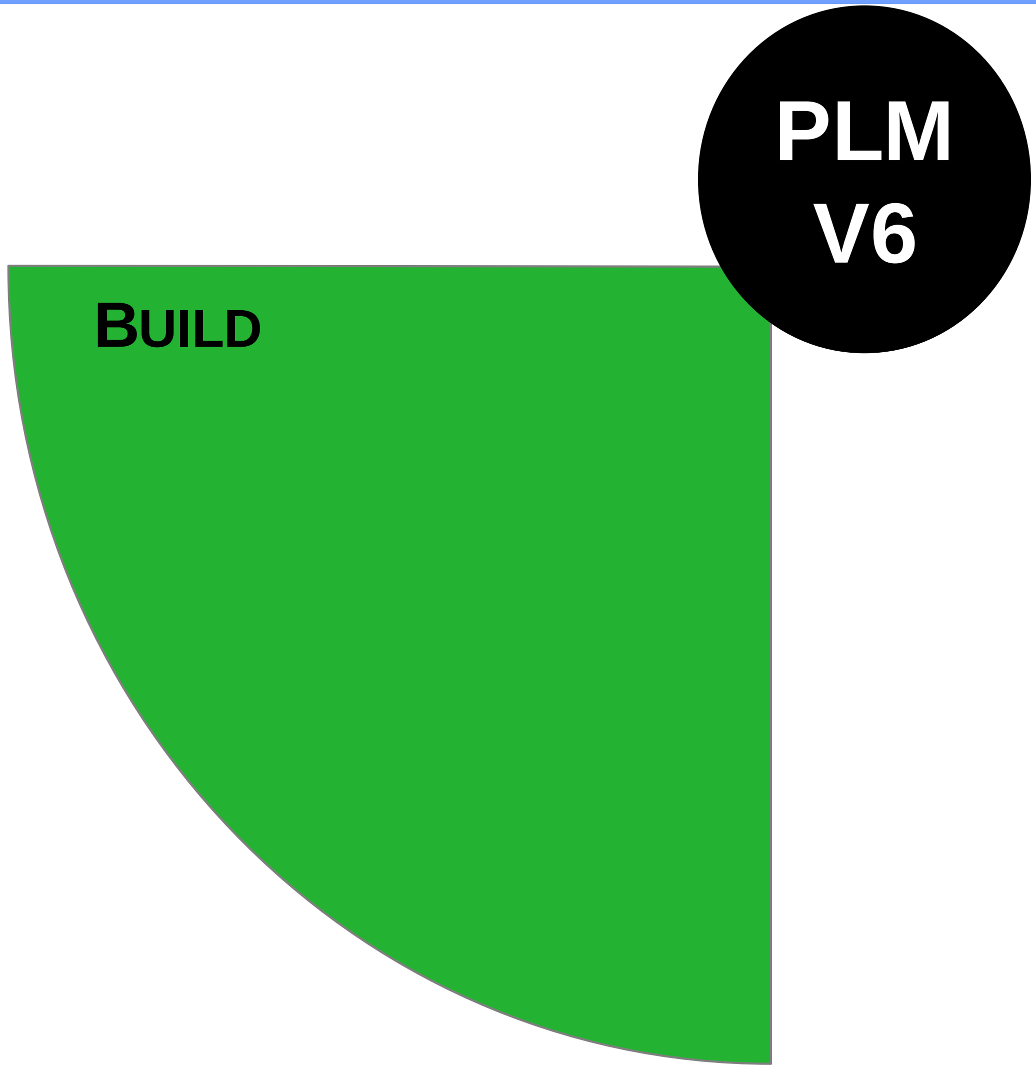


Load Config.
CATIA/CAD
Simulation/CFD
Refined Config.

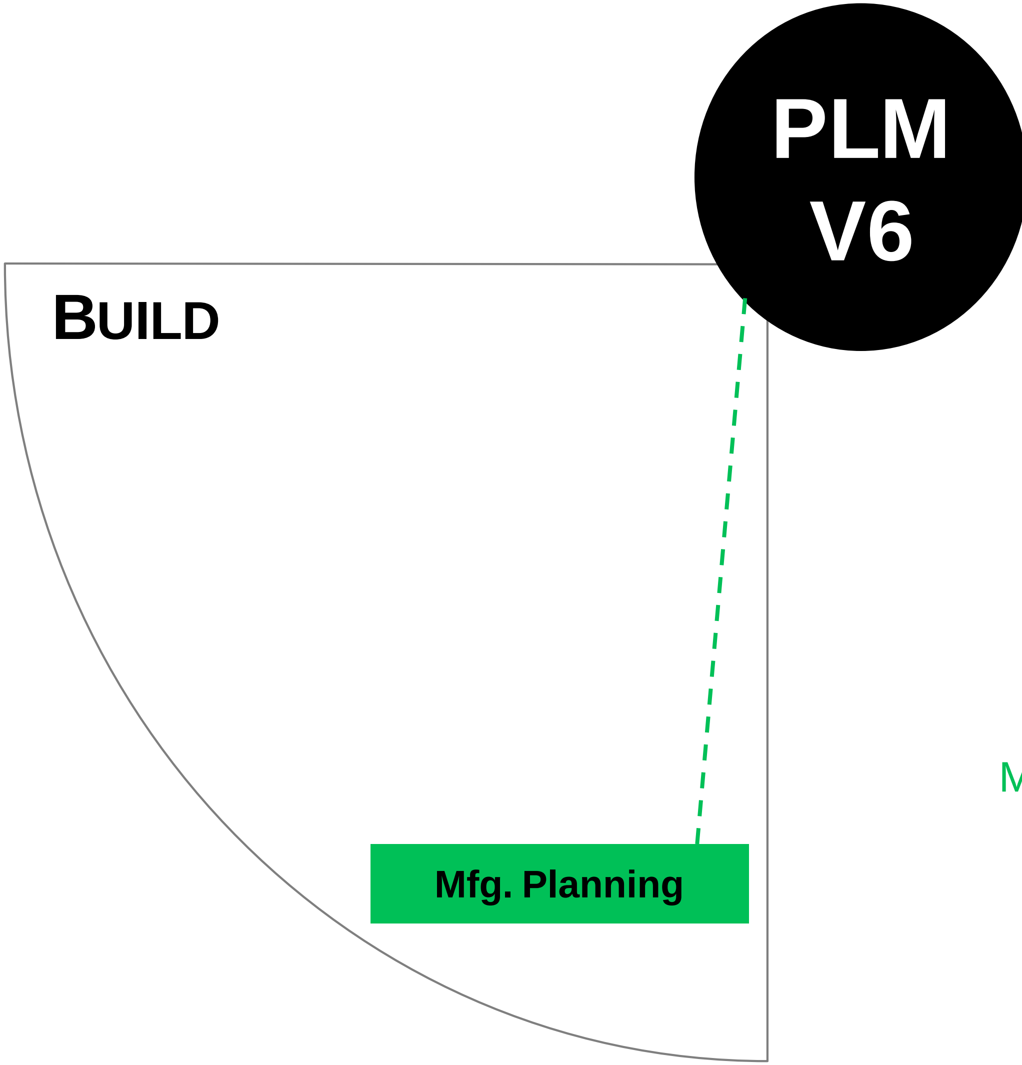
Refinement Follows Body Sizing



The Build Function Transfers Virtual to Physical Prototypes and a Final Build

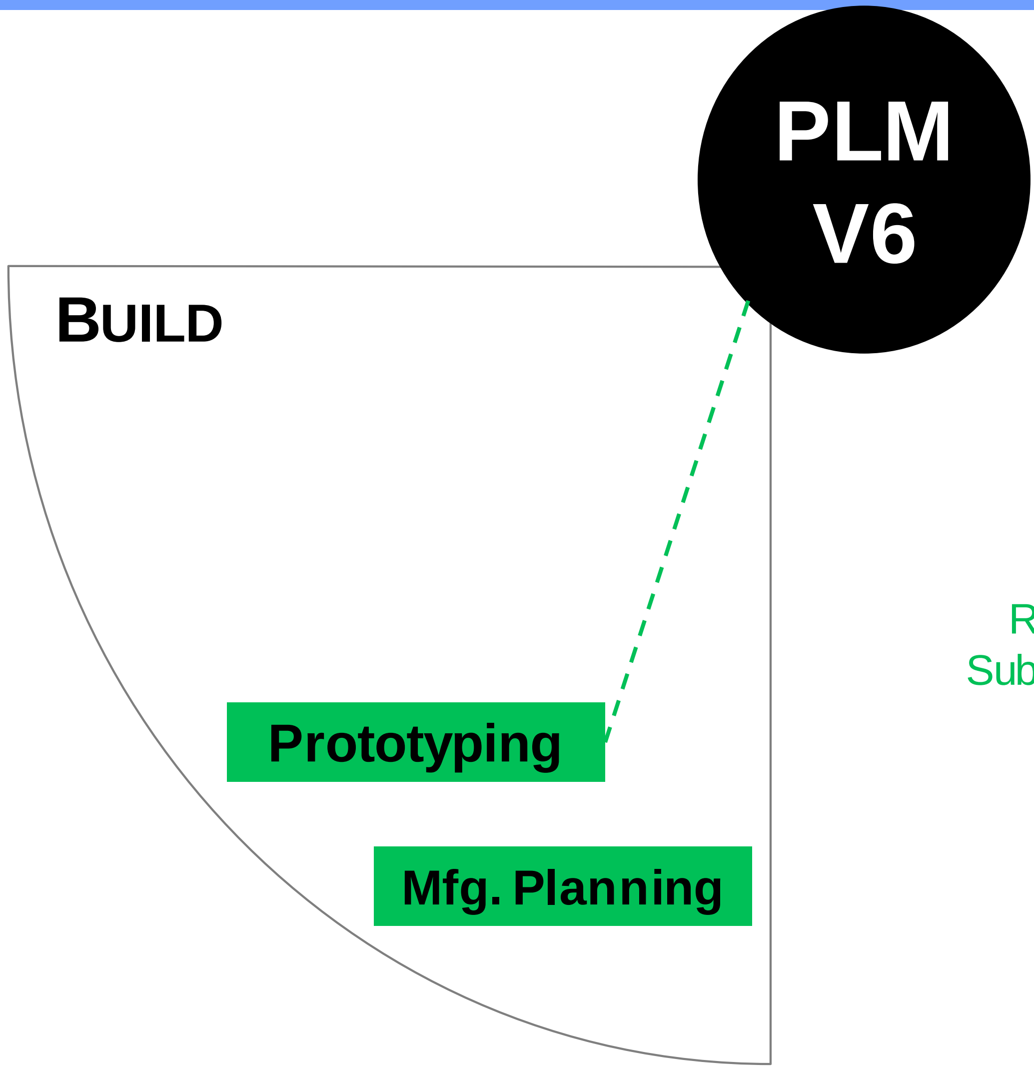


Design and Manufacturing Tradeoffs an emphasis in Manufacturing Planning



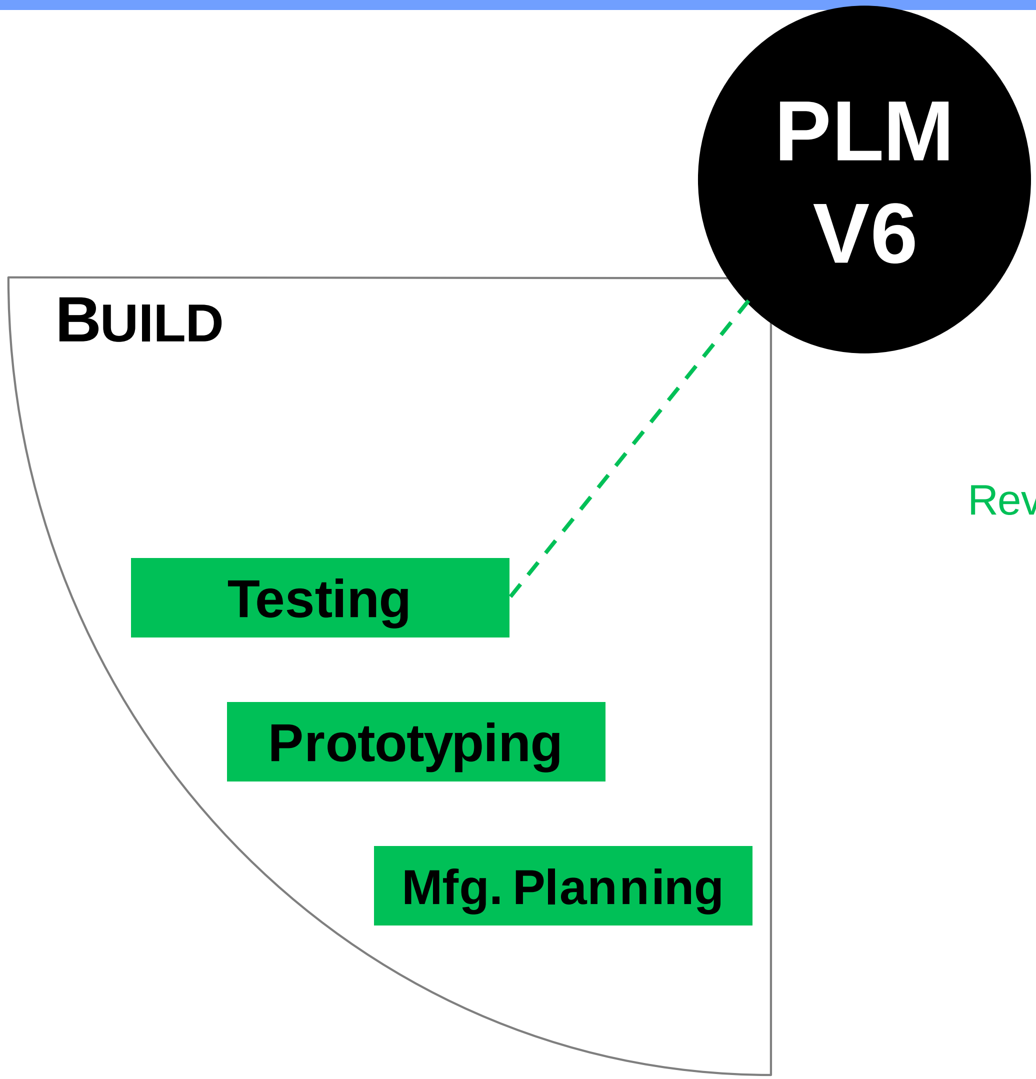
Design Needs
Mfg. Availabilities
DELMIA/CAM

Virtual Prototyping followed by Physical Prototyping



Rapid Prototyping
Subsystems Assembly

Virtual Prototyping leads to Testing of Components & System



Modify Design
Revisit Prototyped Sys.
Reassemble

Final Build Completes the Transition from Virtual to Physical System

PLM
V6

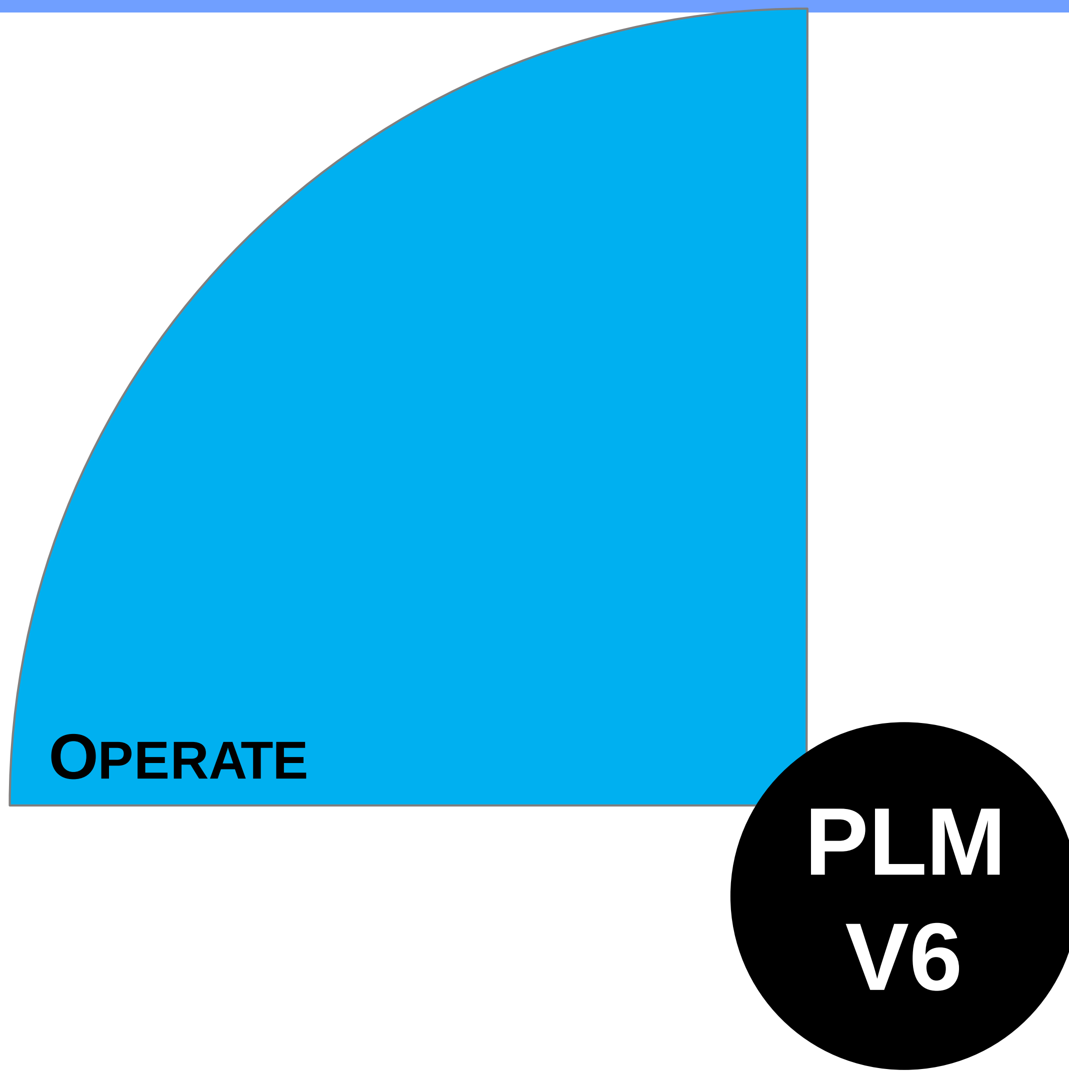
BUILD

Final Build

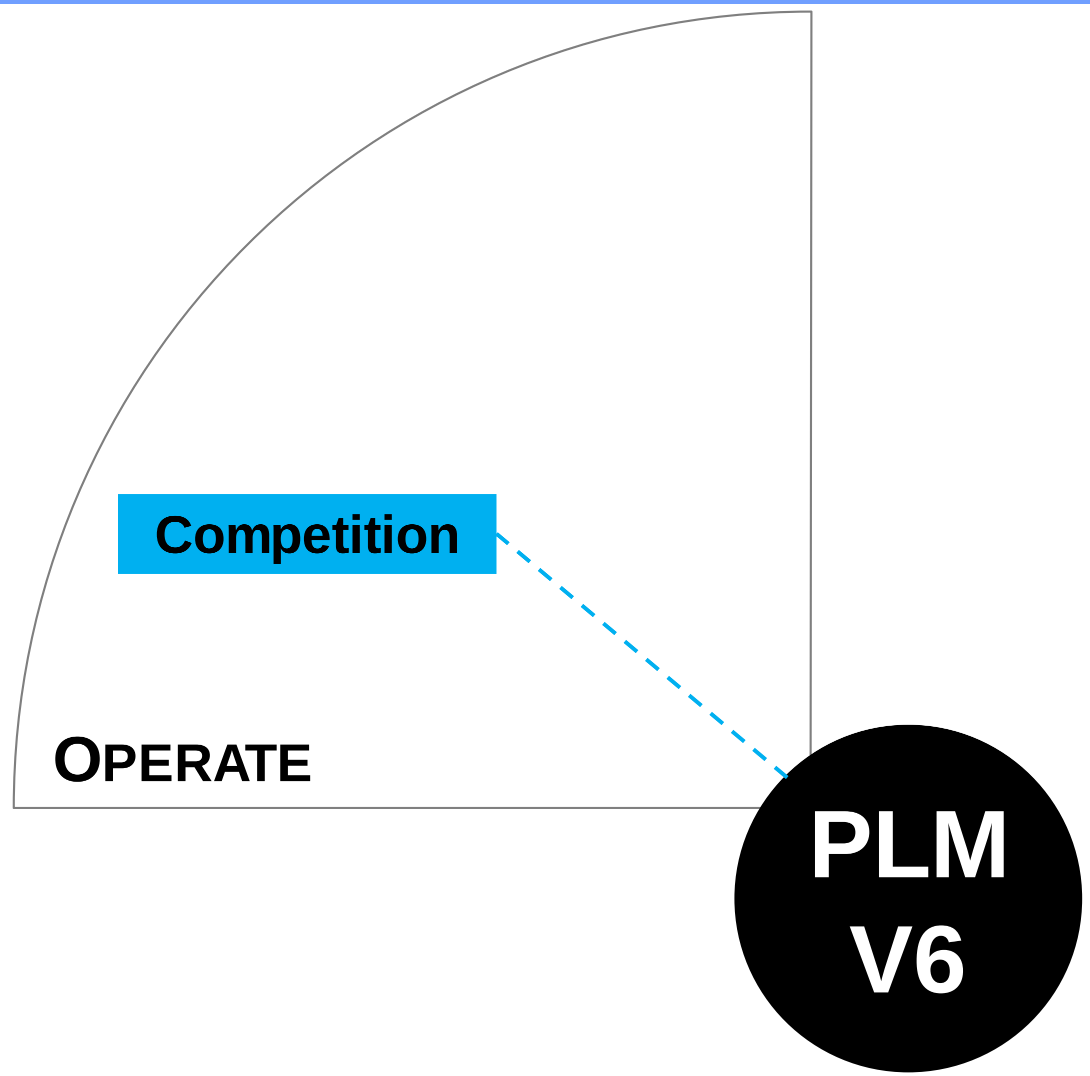
Testing

Prototyping

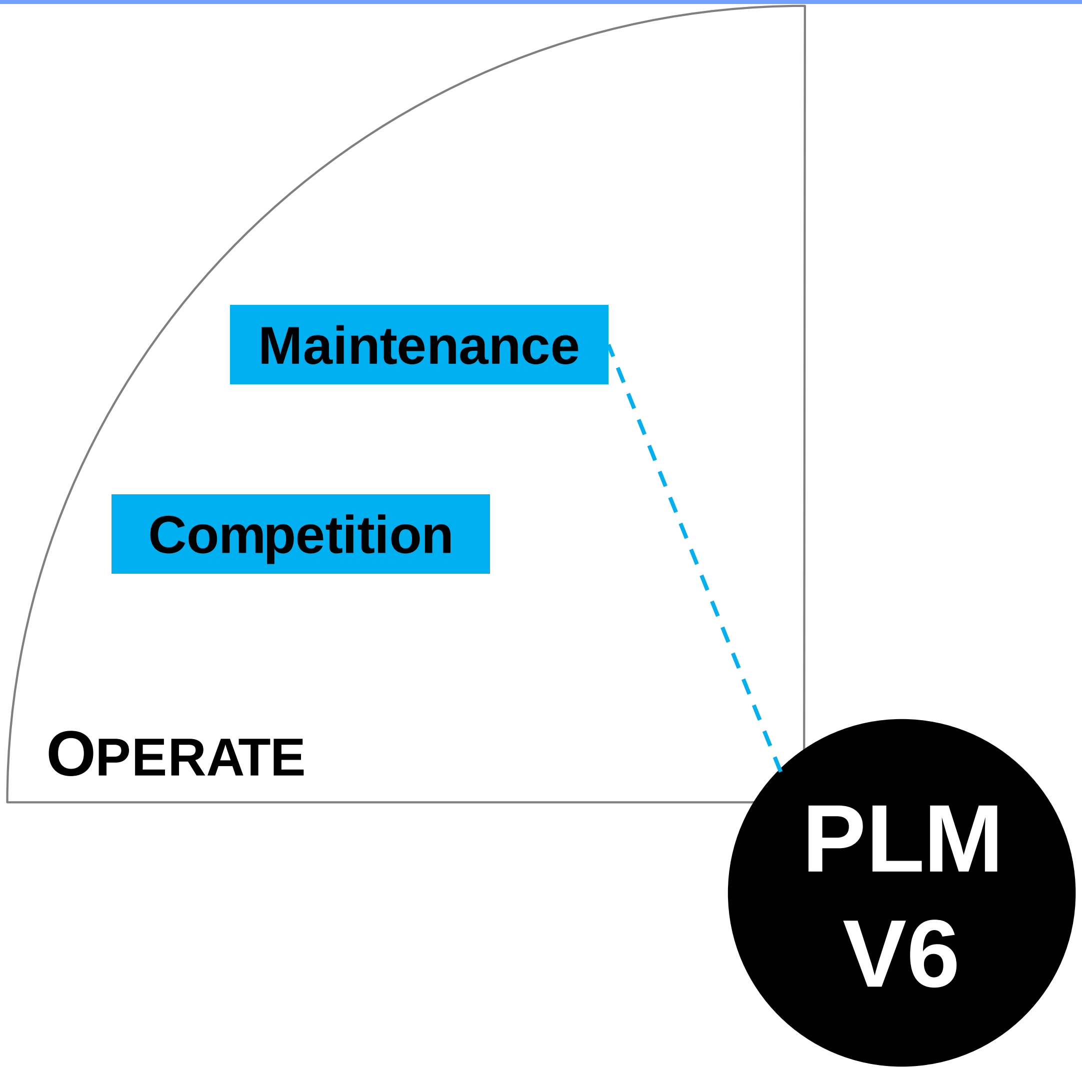
Mfg. Planning


OPERATE
PLM
V6

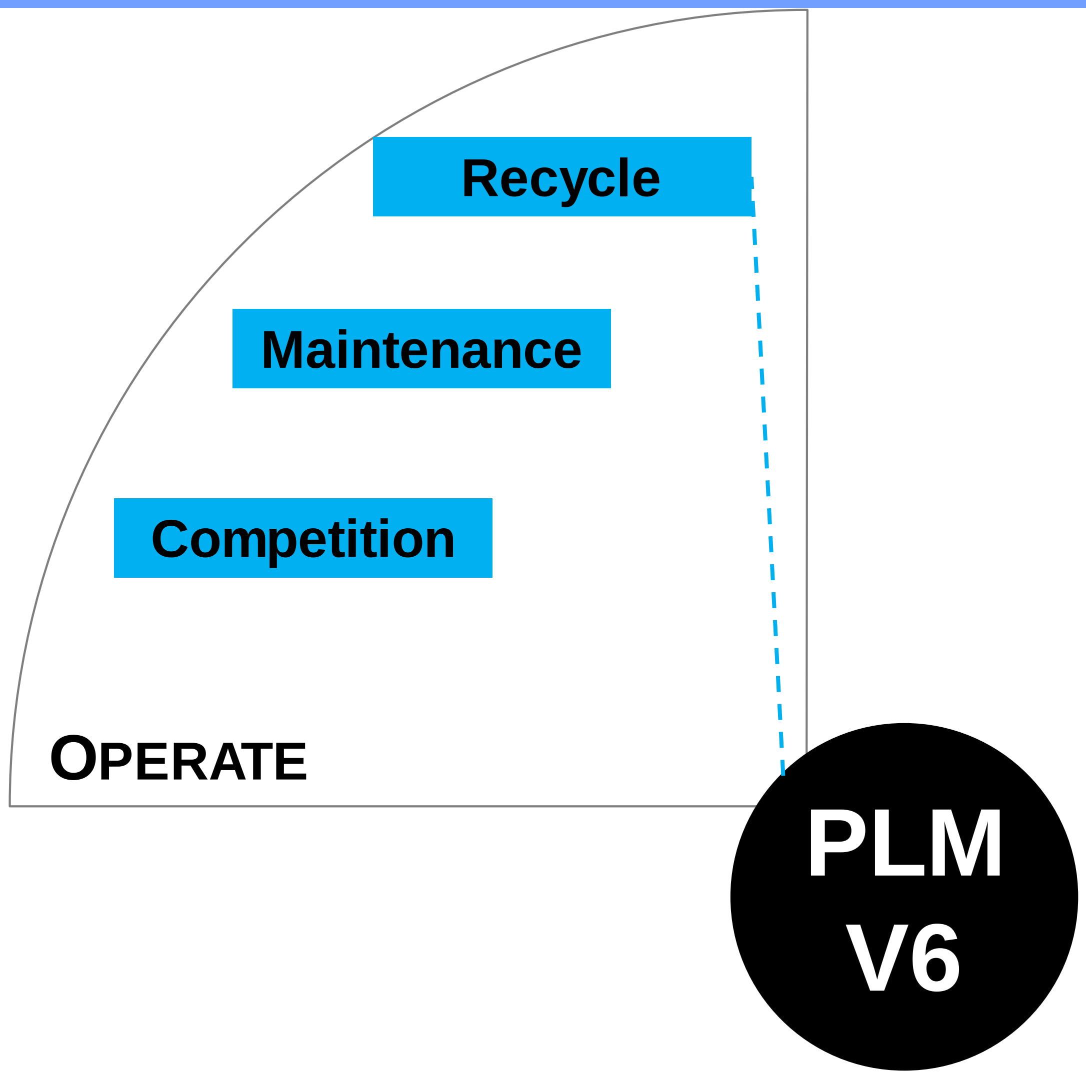
Competition or Fly Off Often Required



Product Support Usually Begins with Maintenance

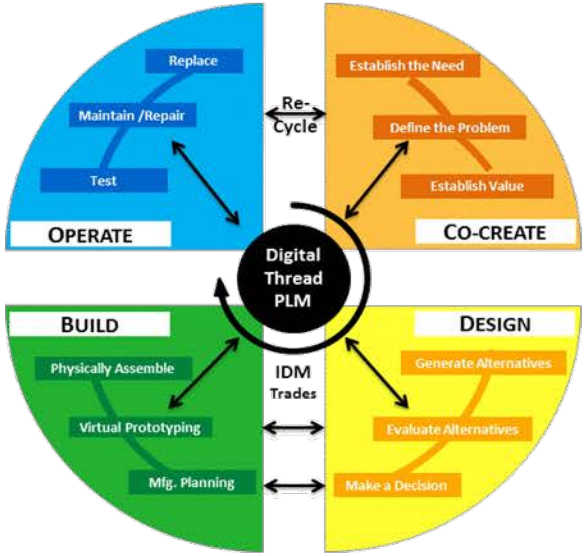


Understanding and Diagnosing the System Often leads to a Recycle and a Second Iteration

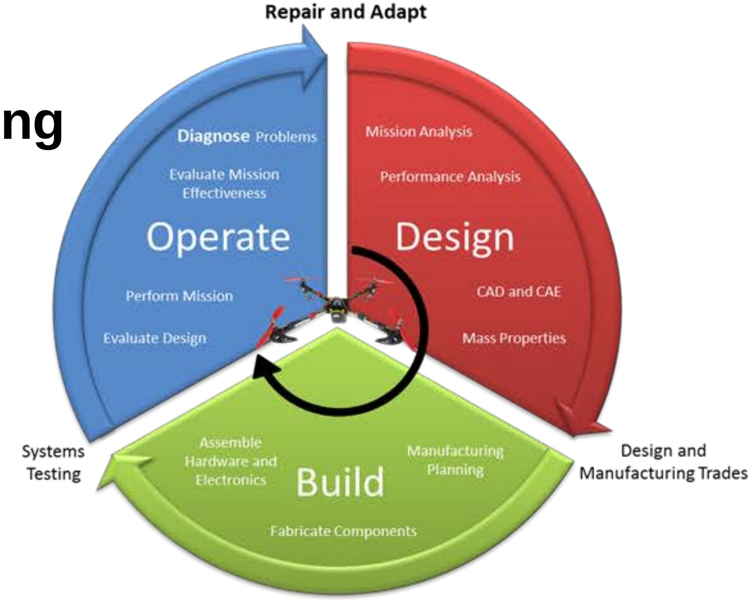


MENTOR2 Requires the Second Iteration of CDBO to Diagnose for Field Repair and Adapt through DBO

- CDBO Iteration to **UNDERSTAND** DBO to **REPAIR** and **ADAPT**

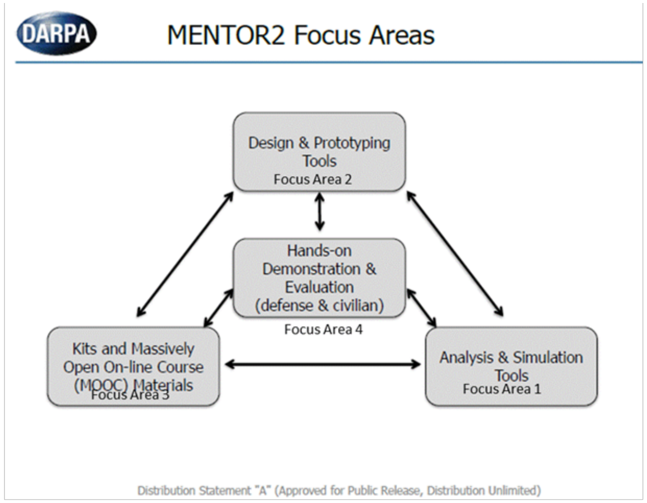


Diagnosing



- The necessary CDBO IPPD tutorials will be developed for MOOC instruction
- The necessary CAD, CAE, CAM Model Based Engineering (MBE) models will be developed for MOOC instruction and Demonstration/Evaluation

Georgia Tech MENTOR2 CREATE QUAD Chart

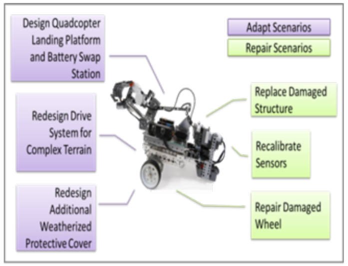


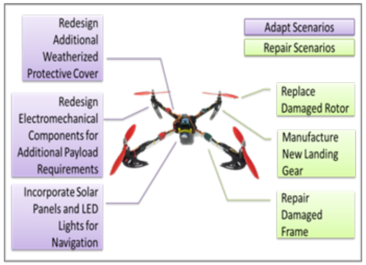
MENTOR 2 GOAL and OBJECTIVES

- Aims to improve defense readiness by improving the secondary and post-secondary school education of those who will be called on to utilize, maintain, and adapt high technology systems in low technology environments
- Achieve this goal by developing and demonstrating new teaching tools and materials in the fields of electromechanical design and manufacturing
- Develop project based curricula employing MENTOR2 design and prototyping tools to teach a deeper understanding of high technology systems, and better enable future competence in the maintenance and adaptation of such systems through the manufacture of as-designed components or the design and manufacture of new components

Georgia Tech CREATE Technical Approach

- Build off of MENTOR Innovations demonstrated in TEAM Summer Camps using a CDBO digital thread approach to develop electro-mechanical air and ground robot project kits for curriculum development and demonstration in an urban warfare environment
- Integrate MENTOR2 contractors for Demonstrations & Evaluations in various environments





Scenario Iterations for Secondary & Post Education Project Kits and MOOC Materials Development

- CDBO Iteration to **UNDERSTAND** DBO to **REPAIR** and **ADAPT**

- The necessary CDBO IPPD tutorials will be developed for MOOC instruction
- The necessary CAD, CAE, CAM models will be developed for MOOC instruction

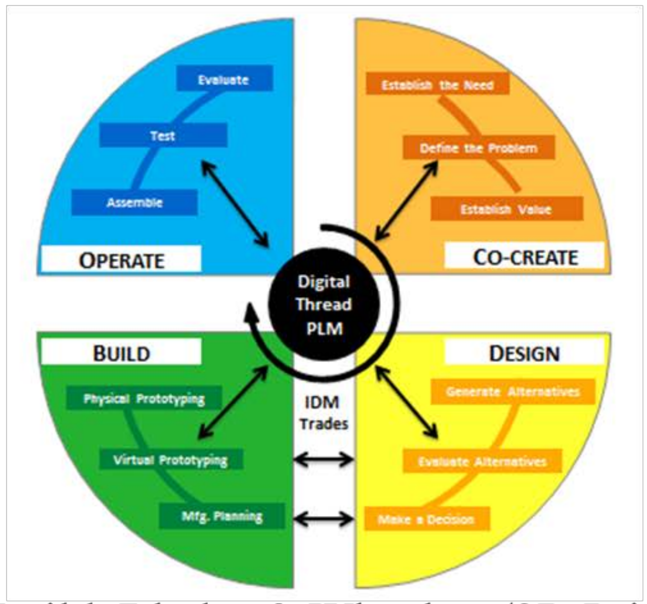
ELYSIUM Parker NORTHROP GRUMMAN BOEING GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2014

Georgia Tech TEAM Summer Camps have applied CDBO for Understanding of Electro-mechanical Systems

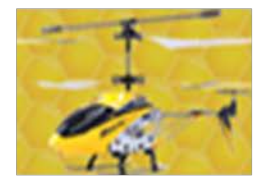
Co-Create, *Design*, *Build* and *Operate* (CDBO) Functions Applied To Redesign of Components for Lego NXT Wind Turbines and Ground Robots, plus Aerial Robots

Operate

Assemble

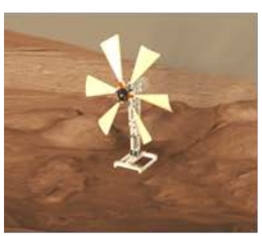


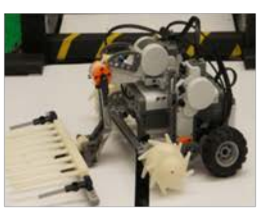
Baselines



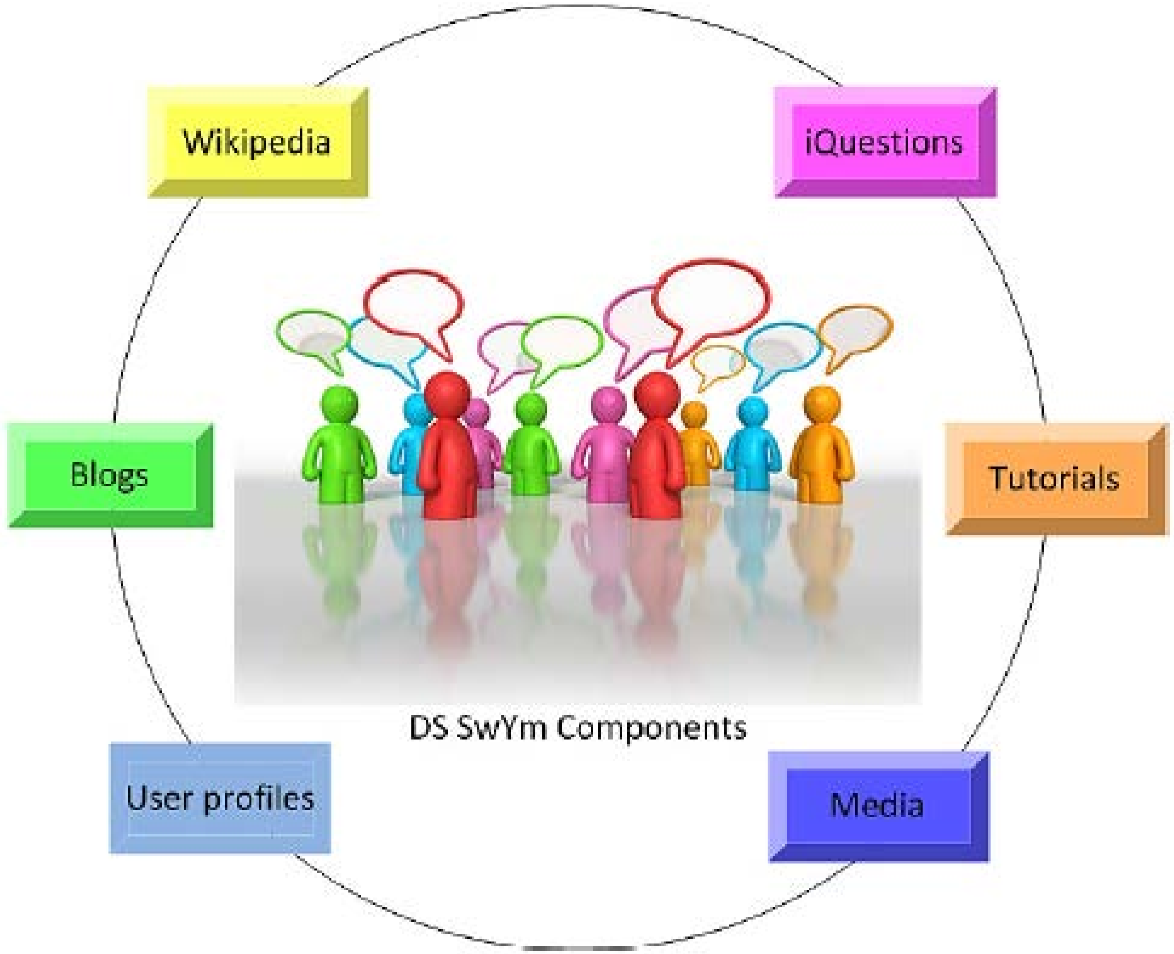
Re-Design Components

Build Blades & Wheels w/3D Printers





Collaboration for Co-Creation has used a Social Network – such as Dassault Systemes See what You Mean (SwYm)



2013 and 2014 TEAM Summer Camp Industry Participants and Sponsors

DS provided PLM Discover Licenses and tutorials to Students

Ford Motor Company provided funding for Students/Teachers & Lectures

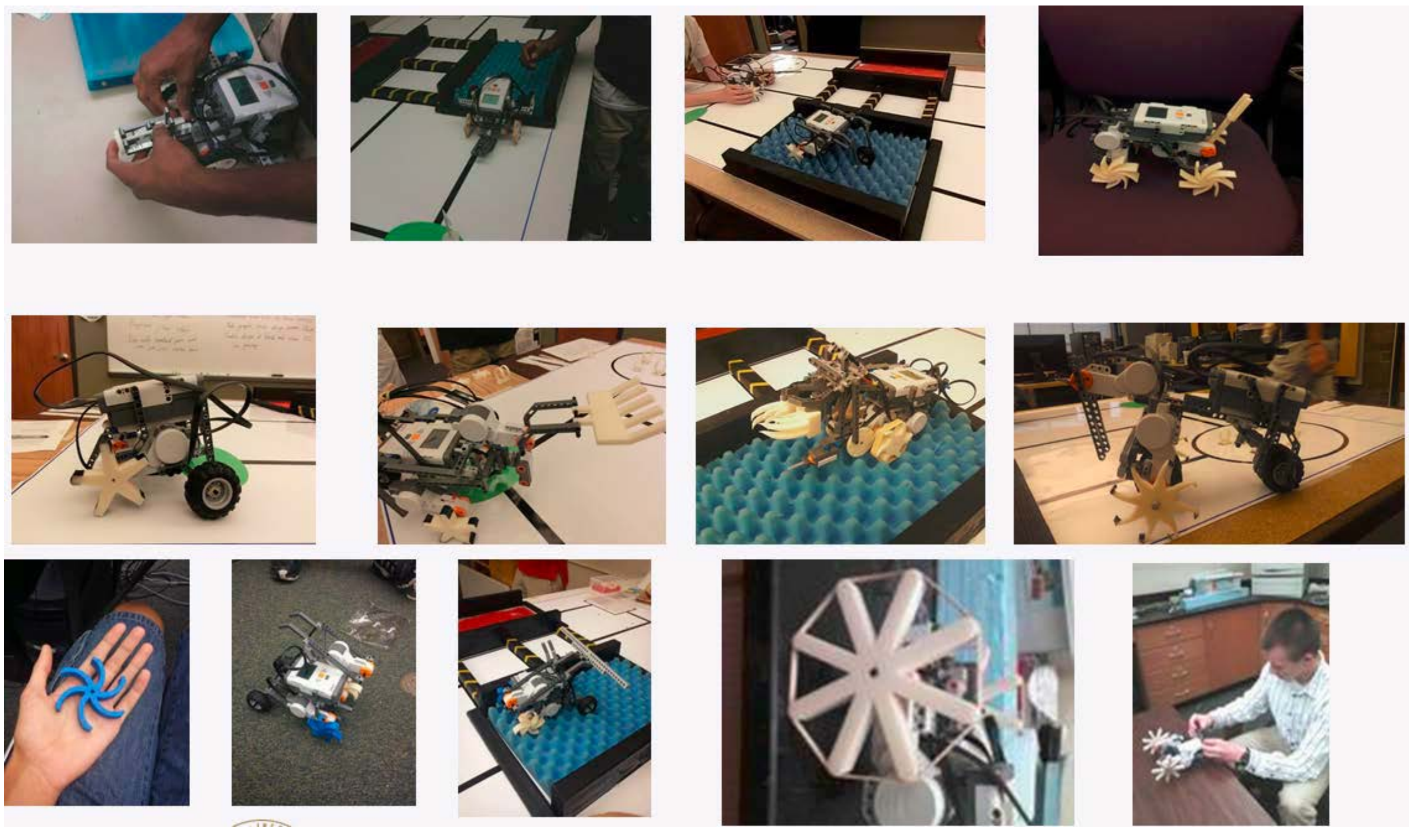
Sikorsky Aircraft provided Funding for Students/Teachers and Plant Field Trip

Stratasys , the leader in commercial 3D printing, provided materials and loaned 3D printers to GIT IPLE Lab, UNH , Kent and Marymount

FDM Solution
- Affordable
- Easy-to-use
- Office friendly
- Reliable
- Durable materials
- Accurate output

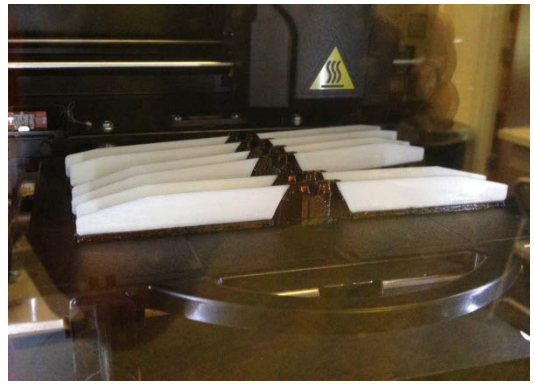
GT TEAM Summer Camp Ground Robot Challenge – Planetry Robotic Mission over Various Terrains

Wheels on Lego NXT Ground Robot were redesigned and built
to be able to operate and provide mobility on a variety of planet surfaces



Design-Build Tradeoffs and Finishing Operations for Aerial Robot Rotor Blades

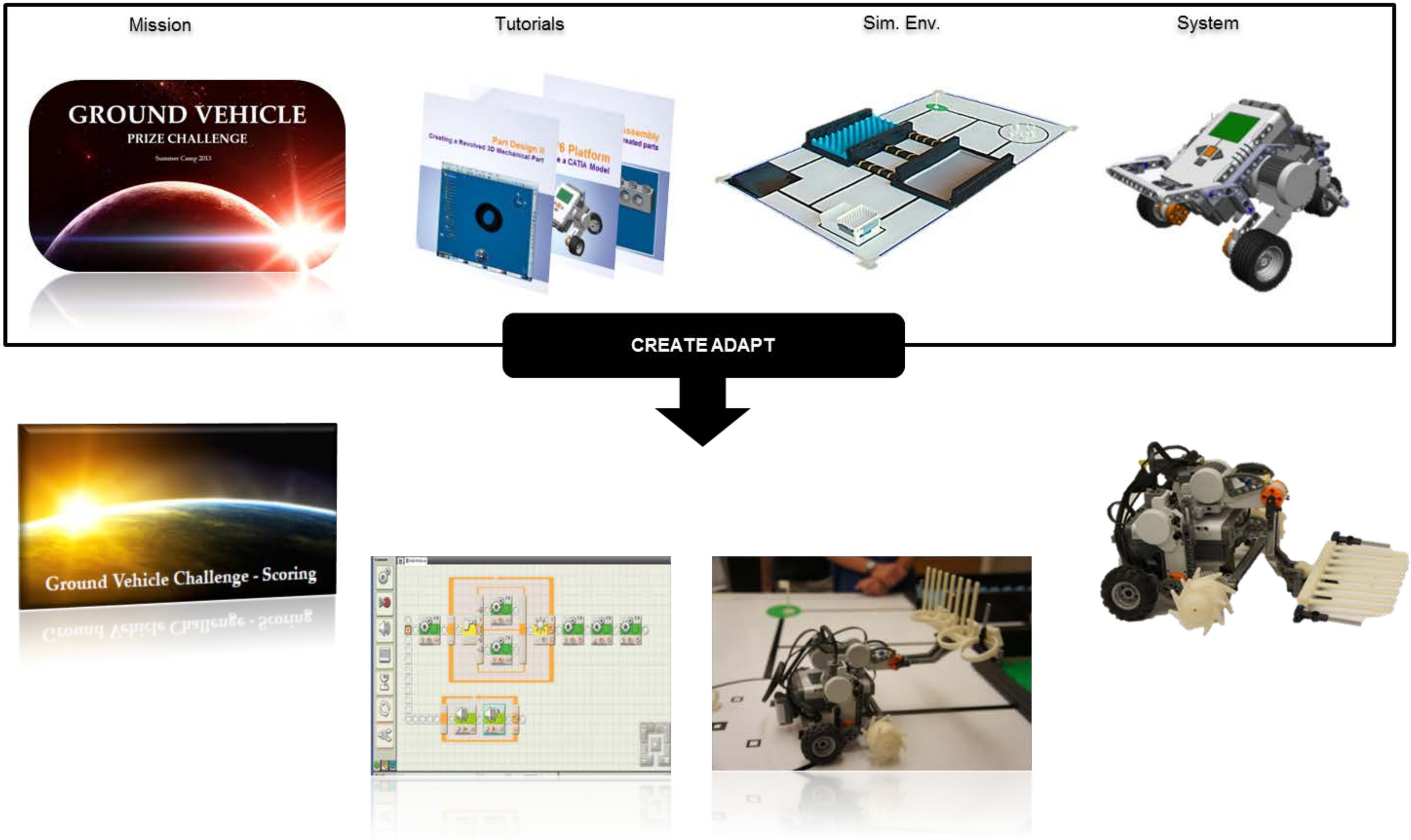
Global Product Data Interoperability Summit | **2014**



Rotor Blades require Low weight and Low Drag; Initial successful Designs required cutting holes in blades to reduce weight and tape to reduce drag

During TEAM Summer Camp at UNH students found during finishing Operations that addition of graphite from pencils reduced drag and weight To produce blades Without holes & tape

Notional CREATE Adapt Function for Ground Robot Scenario

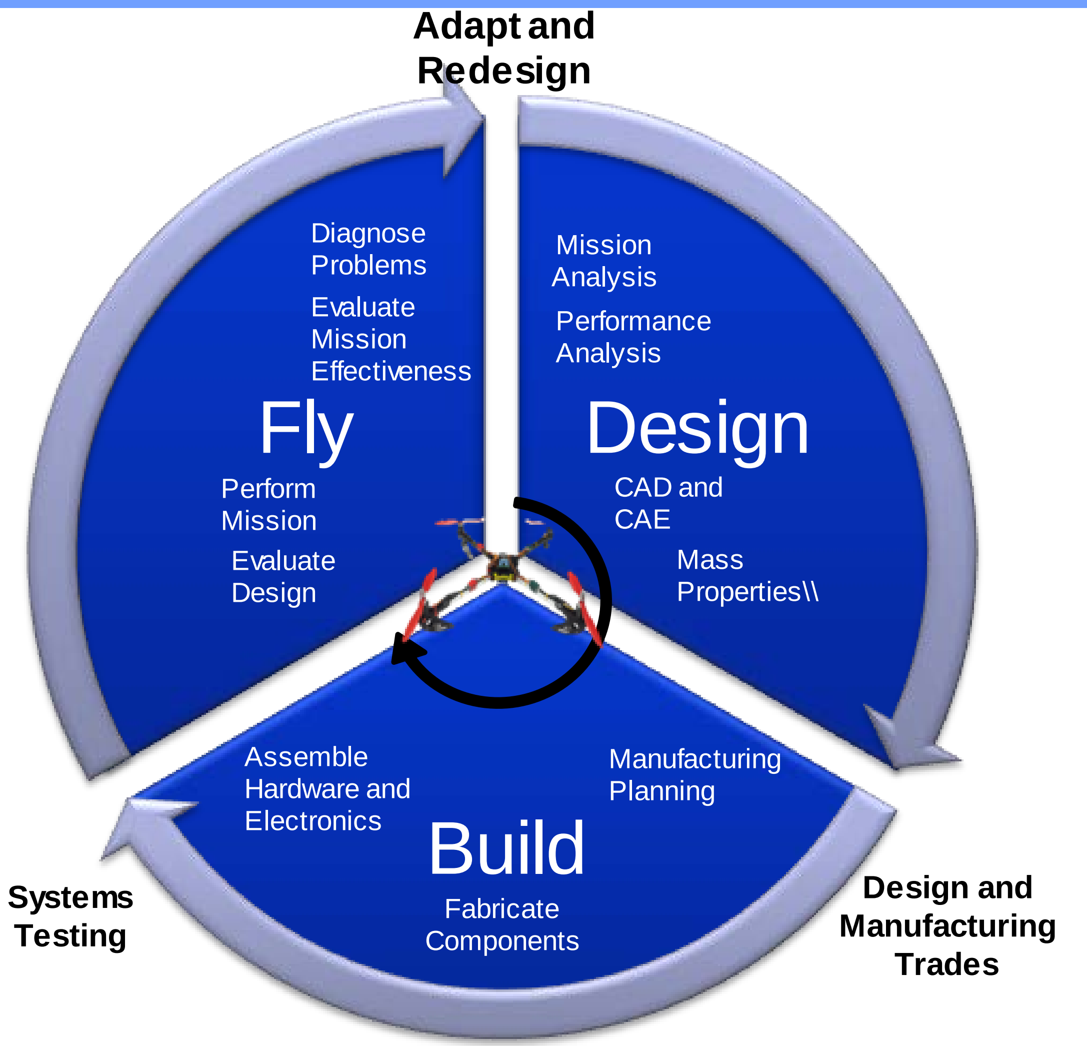


Boeing Sponsored 2014 Brazil Scientific Mobility Project (BSMP) used for Initial Evaluation of CDBP/ DBO Iterations

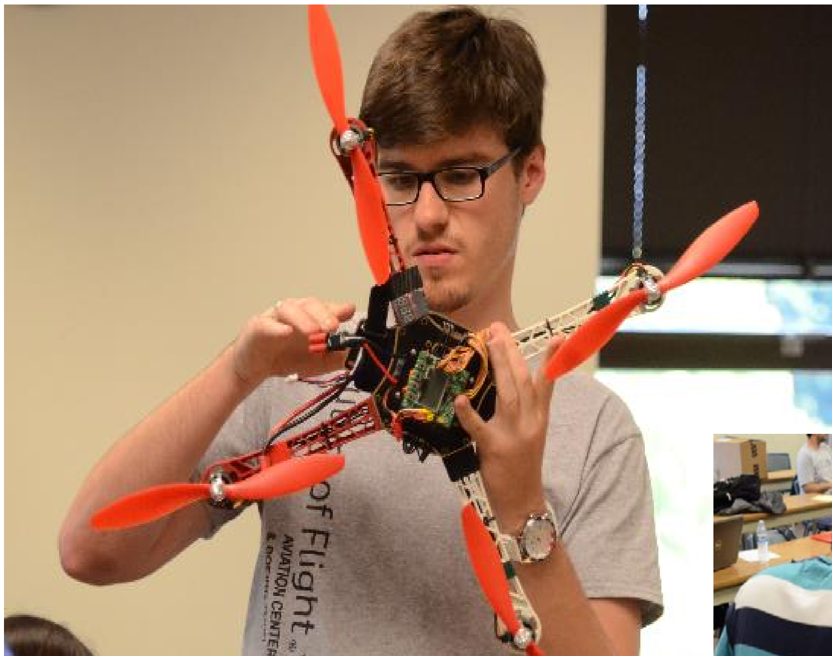
- Boeing and the Government of Brazil have a collaborative agreement for future commercial transport development
- The Brazil Scientific Mobility Project (BSMP) was established as a Boeing summer Internship program for Brazilian undergraduate engineering students studying their final year at U.S. universities under the Brazil Science Without Borders Program
- For the past three years the Georgia Tech Integrated Product Lifecycle Engineering (IPLE) has conducted a two or three week Integrated Design & Manufacturing Tradeoff Course under the Boeing BSMP
- For Summer 2014 the Course consisted of student teams conducting CDBO and DBO for Quad Rotors

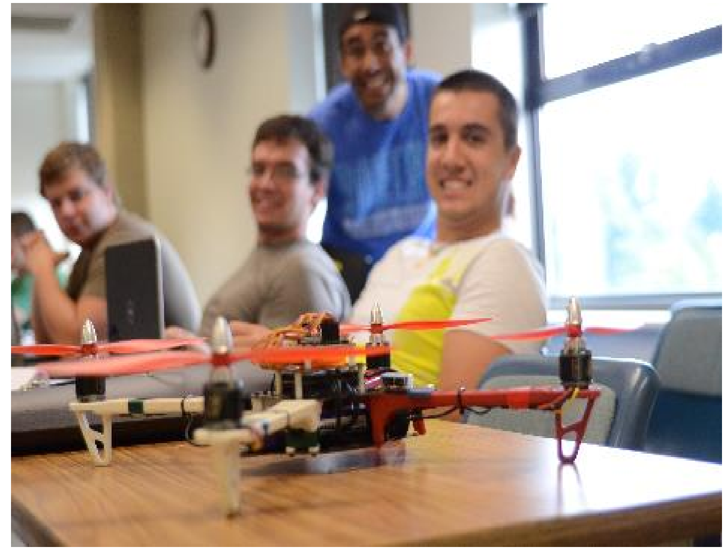
GT IPLE Lab Boeing BSMP Quad Rotor DSO Overview

- **3 week program – 25 students; 5 teams**
  - **Phase 1: 1 week**
    - **Develop *understanding* of rotorcraft mechanics**
    - **Develop *understanding* of electromechanics**
    - **Build baseline vehicle**
  - **Phase 2: 2 weeks**
    - **Employ IPLE principles to *adapt* and *redesign* vehicle to optimally perform new mission**



First Week Student Teams Understood the Baseline Quad Rotor System by Assembling It and Flight Testing





During the Phase 2: Second and Third Weeks the Student Teams Redesigned, Built and Verified to Meet New Missions

- **After the Student Teams Understood the Baseline Commercial Off-The-Shelf Quad Rotor they were given three new missions at the end of the first week**
- **During the Second Week they redesigned their Baseline Quad Rotors for the New Missions**
- **Manufacturing equipment at Edmonds Community College's Material Education Laboratory was used by the Student Teams to build their redesigned components**
- **During the Third Week the Student Teams Assembled and Flight Tested their redesigned Quad Rotors to Verify Accomplishment of the New Missions**

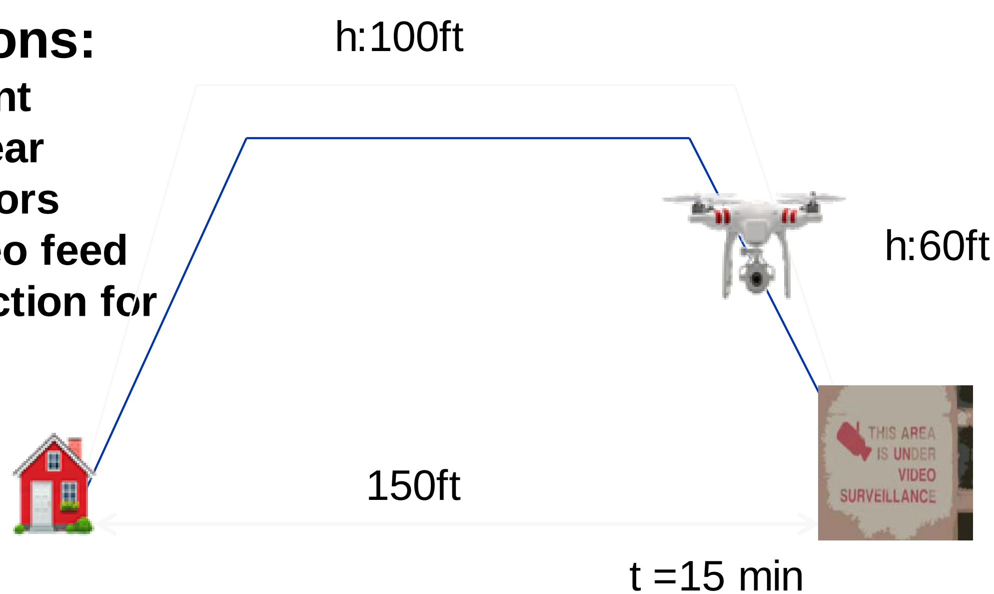
Surveillance Mission

Mission Requirements:

1. Capture video over target location: 150 ft away, 100 ft altitude.
2. Control gimbaled camera independently
3. Continuous operation for minimum 15 min.

Required Modifications:

1. Design camera mount
2. Redesign landing gear
3. Optimize motors/rotors
4. Incorporate live video feed
5. Build weather protection for electronics



New Mission 2 – Assigned to BSMP Student Team 3 and 4

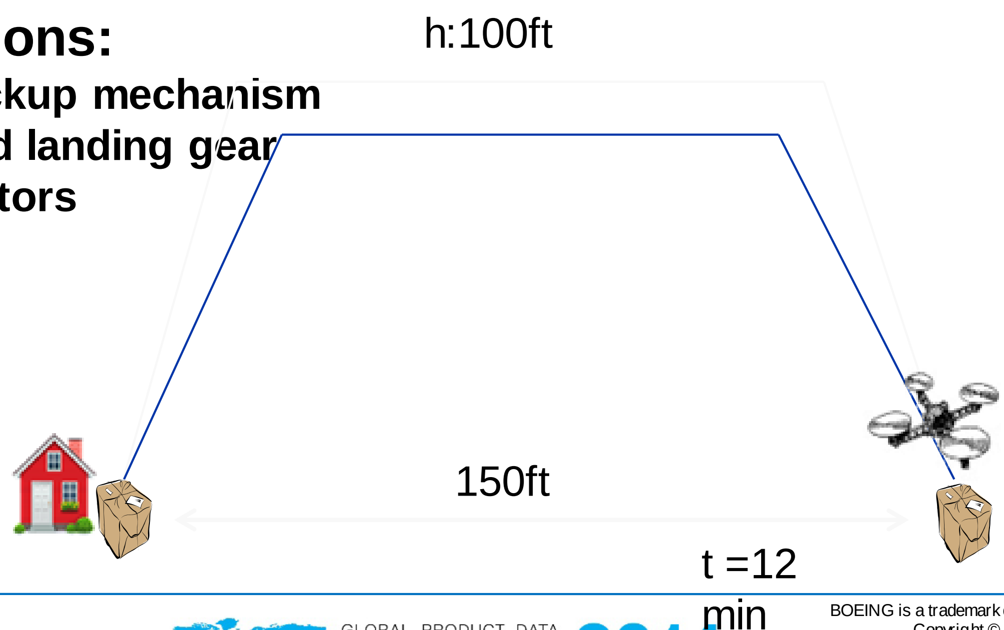
Payload Delivery

Mission Requirements:

1. Pickup 1lb package remotely
2. Drop-off package at different location: 150 ft. away
3. Continuous operation for minimum 12 min.

Required Modifications:

1. Design package pickup mechanism
2. Redesign frame and landing gear
3. Optimize motors/rotors



New Mission – Assigned to BSMP Student Team 5

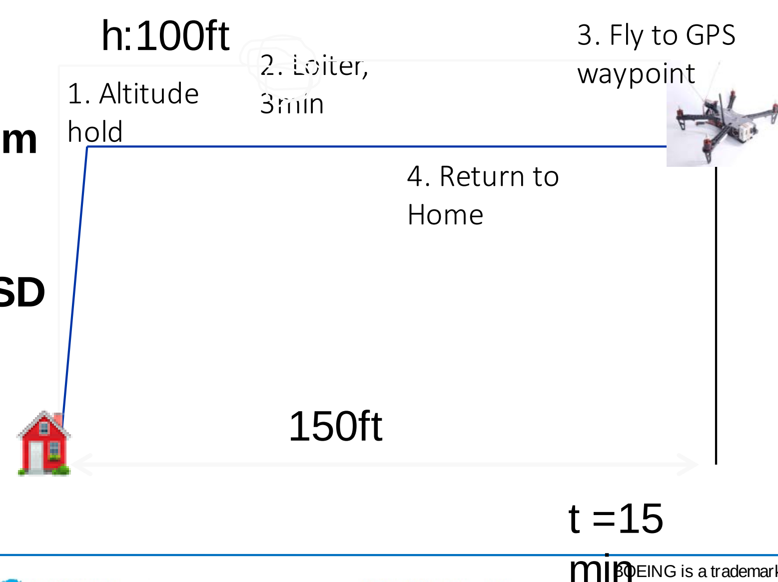
Autonomous Flight Mission

Mission Requirements:

1. Autonomous takeoff and landing
2. Follow predefined GPS locations
3. Continuous operation for minimum 15 min.

Required Modifications:

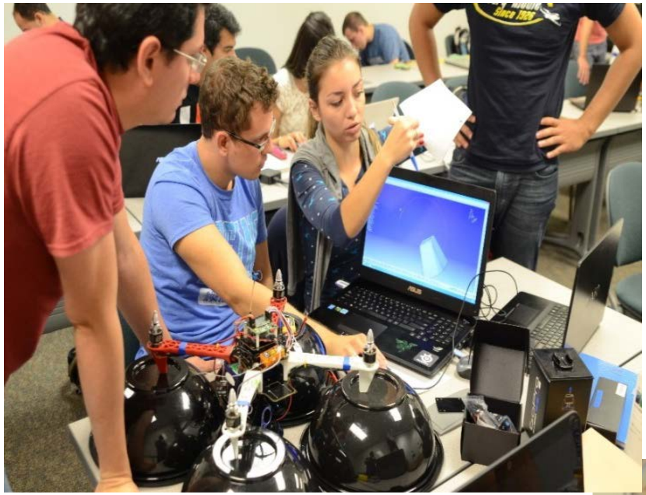
1. Install Arduino autopilot system
2. Install live video feed
3. Integrate GPS and compass
4. Integrate telemetry and live OSD
5. Redesign frame
6. Optimize motors/rotors

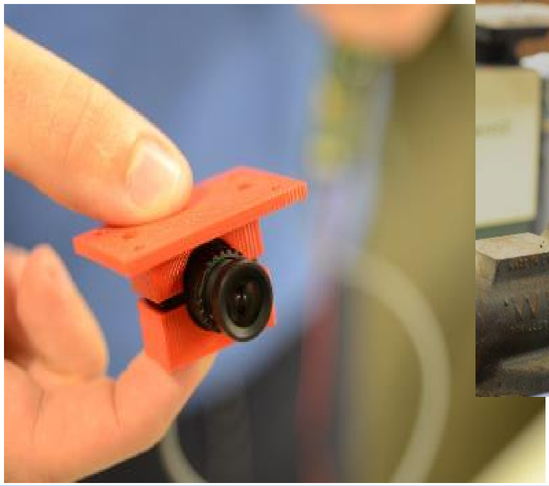


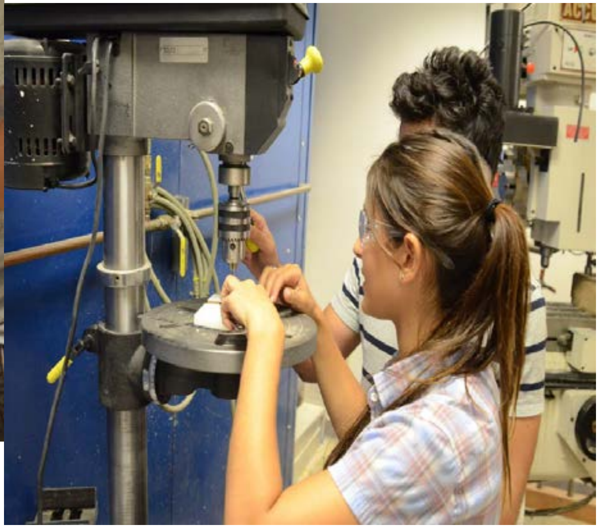
BSMP Student Teams Competition Points Scheme

- **Mission Completion – 25 pts**
  - **Meet all mission and performance requirements**
- **Aesthetics – 25 pts**
  - **How "good" can you make your vehicle look**
- **Creative Design Solutions – 25 pts**
  - **Creative solutions to meet requirements**
- **Quality of build – 25 pts**
  - **Solutions to ensure flight is stable and structurally durable**

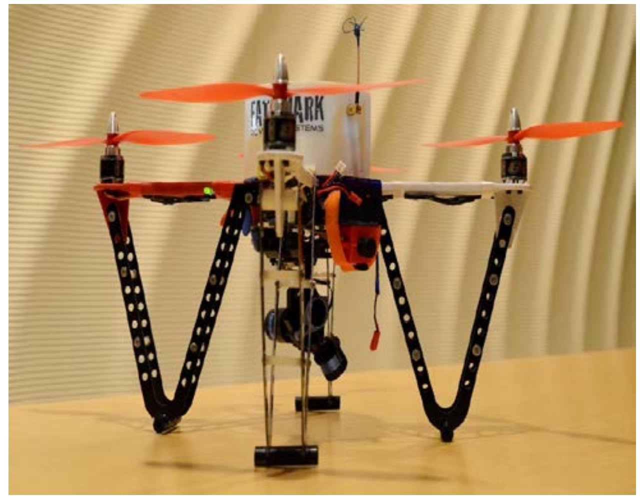
Pictures of BSMP Student Teams Modifying and Rebuilding their Baseline Quad Rotors during Phase 2

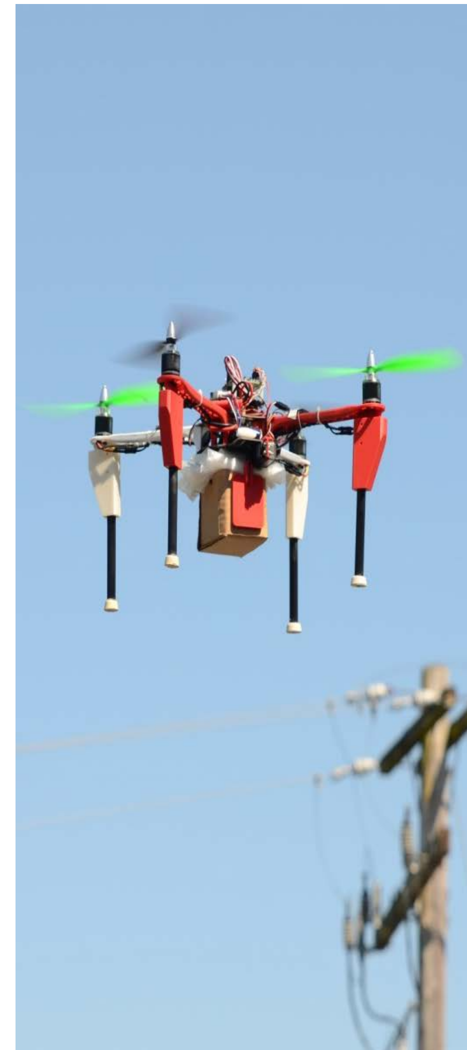






Pictures of BSMP Student Teams' Final Quad Rotor Designs





A BSMP Student Team finishes their Final Payload Mission Verification

BSMP Student Team Member Preparing for Final Demo

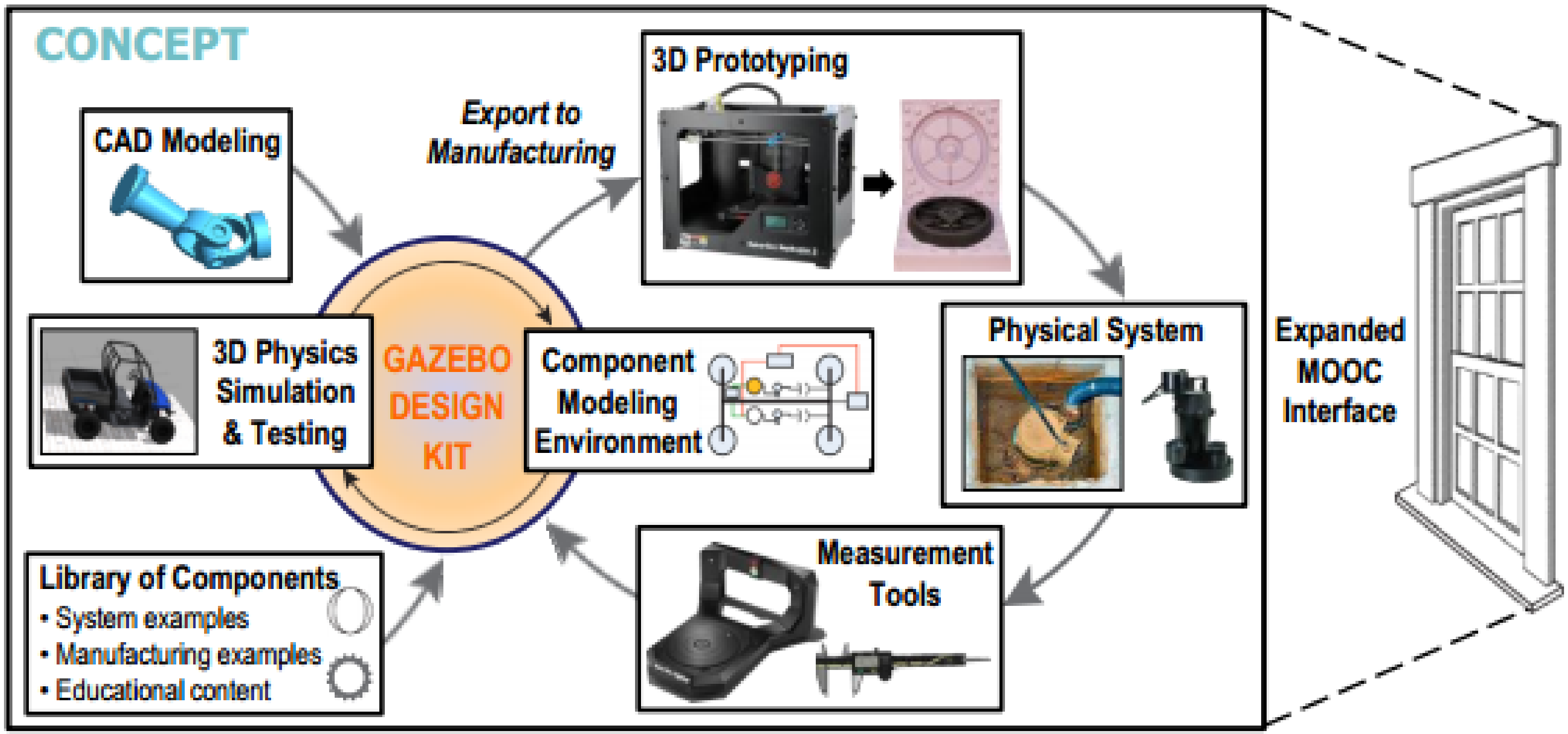
BSMP Student Team Member Prepares for Takeoff

Proposed Objectives for GT MENTOR2 CREATE (Continued)

3.) CREATE will develop and improve student and instructor access to the latest design and manufacturing methodologies and hardware, and further develop those technologies for the educational and training environment.

4.) CREATE will also evaluate and develop tools to catalyze authentic, project-based education, where the need for technical understanding is organic to the projects being done and will address the need to assess student performance by integrating assessment with education through authentic problem-based projects.

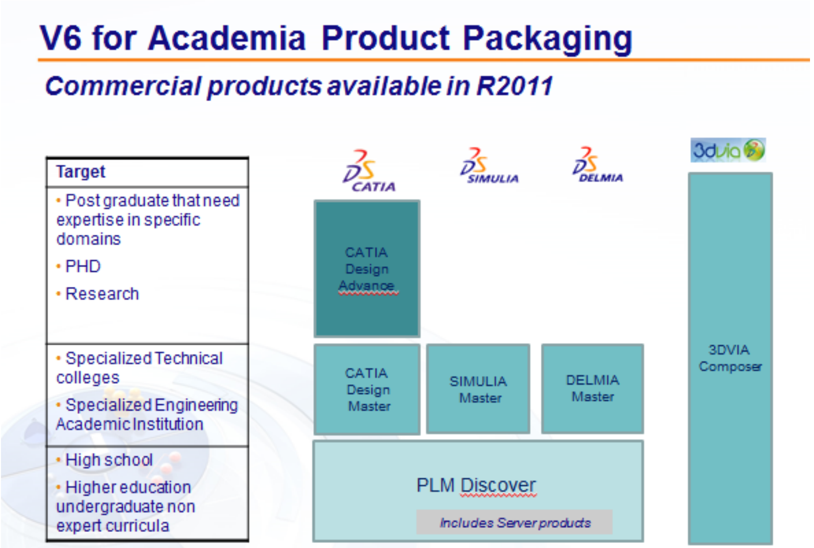
Notional Illustration of MENTOR2 Focus Area Integration (From SRI, MENTOR2 Contractor)



Workflow diagram illustrating iterative design and test loops within the simulation/analysis package "Gazebo Design Kit" as well as design-test cycles between the virtual and physical systems. A MOOC interface containing exemplary projects is provided for training on the SiMPLE system.

CREATE provide Instructors and Students access to the latest design/manufacturing methodologies & hardware

Global Product Data Interoperability Summit | **2014**



FDM Solution

Affordable

Easy-to-use

Office friendly

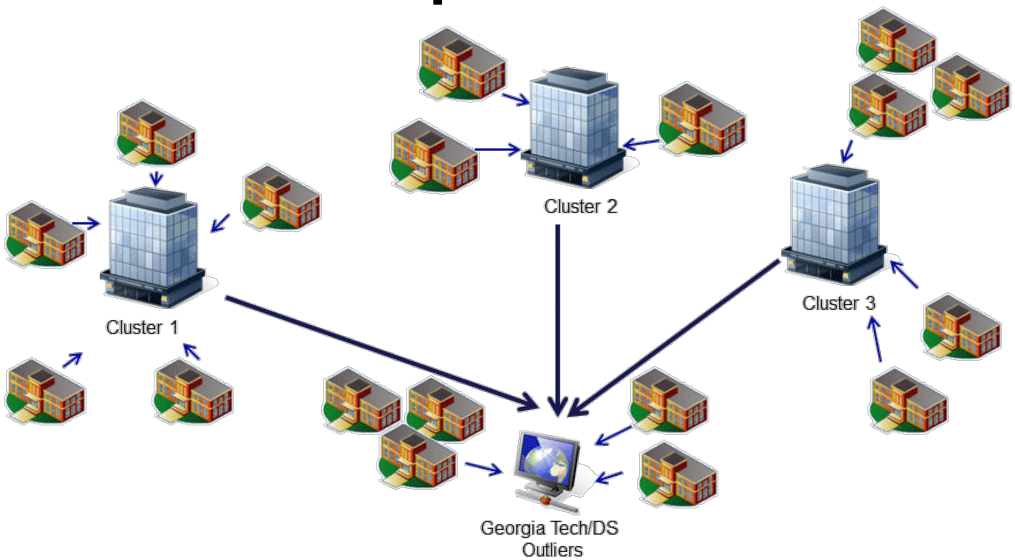
Reliable

Durable materials

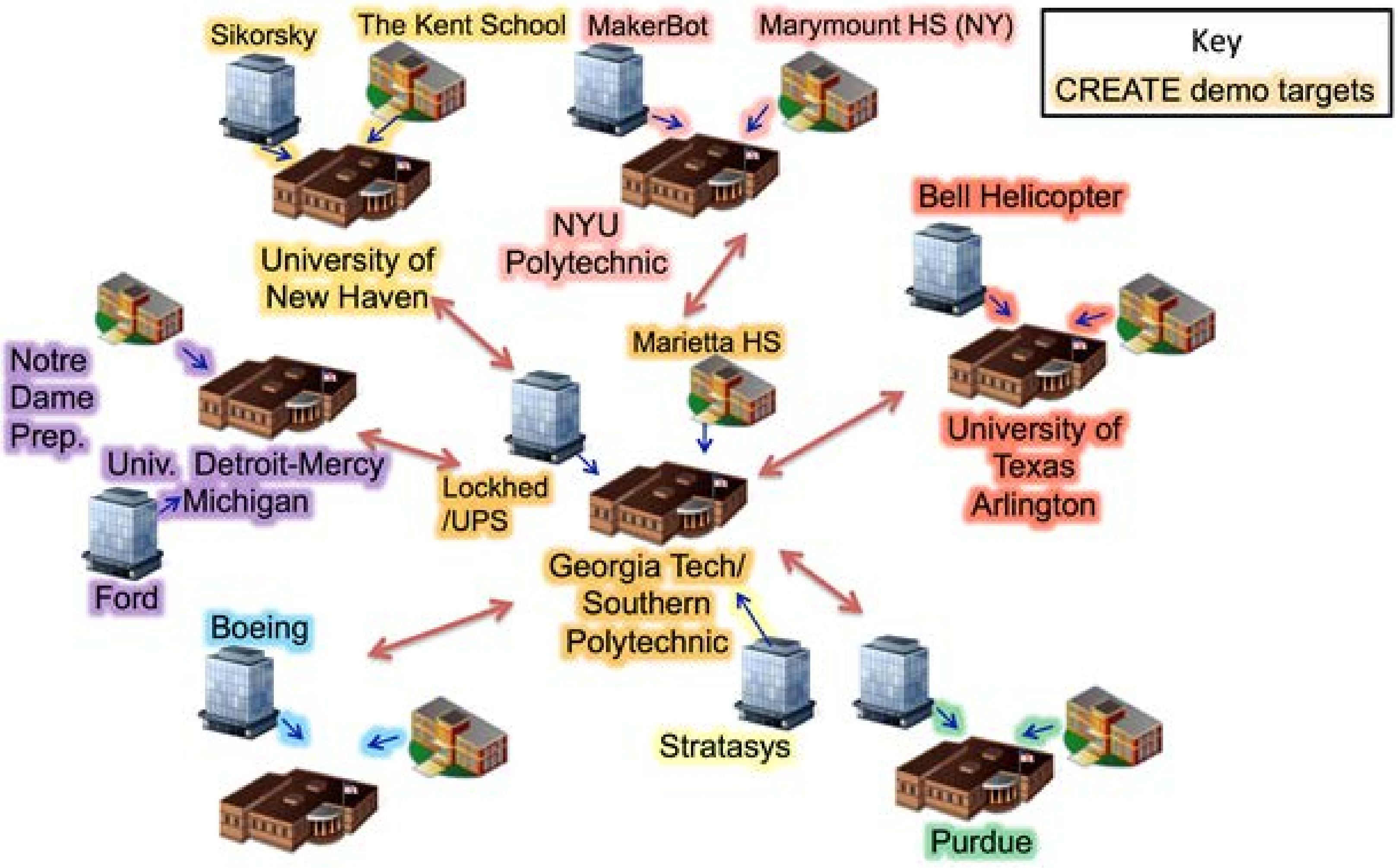
Accurate output

Proposed Objectives for GT MENTOR2 CREATE (Continued)

5.) CREATE will achieve self-sustainment and broad dissemination through regional cluster partners including high schools, universities and industry supporters following development through franchise implementation, well documented systems/APIs, and open source code. Example illustrated Below:



GT MENTOR2 CREATE Plan is to Build Off of TEAM Summer Camp Clusters that have and are being Expanded



Summary and Conclusions

- **We applaud DARPA for their Vision of an educational testbed for developing and applying Digital Data Interoperability for civil and military complex systems understanding, repairing and adapting**
- **We at Georgia Tech and the other MENTOR2 contractors are excited about starting to help DARPA and industry explore and implement this educational testbed in austere environments**
- **We appreciate our industry partners and sponsors in developing the TEAM Summer Camps over the past three years which have proven the CDBO approach for innovative and creative product development at the Secondary and Post-Secondary Education levels**
- **We feel that CDBO can establish the Understand Function while a second iteration DBO can provided the Repair and Adapt Functions, as initially demonstrated in the Boeing BSMP**
- **We thank Boeing for the opportunity to initially demonstrate DBO for the Quad Rotor BSMP**