2018 Annual INCOSE
Great Lakes Regional Conference
SYSTEMS AT THE CROSSROADS
17 - 20 October 2018 | Indianapolis, Indiana

Performing Requirements Analysis in a Limited and Constrained Environment, an Interactive Event Between INCOSE and Indiana FIRST

Presented by
FRC Team 1024, The Kil-A-Bytes and
Three Distinguished Panelists

Panel Overview

- “Reverse” Panel
- Integrated and Interactive Discussion Between:
  - ***FIRST*** Robotics Team 1024, The Kil-A-Bytes
  - INCOSE Panelists
- Reviewing an exciting example of high schoolers managing a complex system’s life cycle with extreme constraints on their processes

Agenda

- 15 minutes: Panelists present “position statements”
- 30 minutes: Team presentation
- 20 minutes: Team/Panelist discussion
- 20 minutes: Discussion opened to Audience

Moderators

- Jason Sherey
  - INCOSE GLRC 2018 STEM Lead
- Chris Osborne
  - Indiana FIRST Program Director

Panelists

- Mike Celentano
- John Spivy
- Mike Vinarcik

Mike Celentano, ESEP

Roche Principal Systems Engineer
Roche Adaptive Technologies Program Manager
INCOSE Technical Director

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Mike Celentano has been influencing the Medical Diagnostics field since 1987. He has experience in systems engineering, advanced research, engineering management, product development, and technology management.

Mike has dedicated his career to developing multi-disciplined instrumentation used to diagnose & monitor disease to ultimately help improve the quality of healthcare globally. He has worked for Technicon, Miles, Bayer, Seradyn, UMM and Roche. Mike is currently the Program Leader for Global Adaptive Technologies at Roche Diagnostics Diabetes Care in Indianapolis. His charter is to evaluate and expedite new technologies and features that could benefit Roche's diabetes patients, caregivers, and payers.

Mike has a B.S. in Electrical Engineering from N.Y.I.T. He achieved SE certification at the highest level in 2017. Mike has been granted many global patents related to medical diagnostics. Through his involvement in INCOSE Mike is striving to make Systems Engineering practices more common-place in the Biomedical Industry. Mike founded the INCOSE International Healthcare Working Group. He currently serves on the Board of Directors for INCOSE at the international level.

Mike Celentano Position Statement

Requirements Analysis (RA) under severe time pressure often results in re-architecting. Ironically, re-architecting usually takes longer than the time required for a proper RA. However, that does not mean that the RA has to be long. In fact, a sufficient RA can be done in a lean and iterative (ie: agile) manner with success. Of course, assuring consistency & clarity in the elicited requirements is essential. But early allocation of requirements can help to prioritize the effort. Since a key output of the RA is the System Architecture it's important to identify the requirements that drive the architectural decisions. By focusing on these first, the architecture can be made robust early in the design life cycle. Although the logical architecture can be quite different than the physical architecture, but it does not have to be. Synchronizing these early can save a lot of time. Also, building in flexibility around constraining requirements will help the team make quick changes later on. Failing fast and early is best, so identifying & prototyping the riskiest areas early helps to solidify the architecture quickly. On one hand these methods make the RA seem longer and fuzzies the boundary between process steps, on the other hand these methods allow more concurrent systems engineering and therefore, accommodates a compressed schedule with little sacrifice to quality.

John D. Spivy has been involved in Aerospace field since 2001 at Rolls-Royce Corporation. John transition to the role of Technical Specialist System Engineering Methods formally in 2017. He is focus on enabling the global Rolls-Royce engineering processes and methods associated with requirements capture, validation evidence, design definition, and verification compliance. As longer term focus, John is supporting the paradigm change toward ‘digitization’ throughout Rolls-Royce. Through involve in INCOSE John is sharing and gathering industry knowledge to aide development of Rolls-Royce going forward. John is also advocate of teaching systems thinking as part of education and has been involved with the Purdue’s Engineering Projects In Community Service (EPICS).

John Spivy Position Statement

Projects are a balance of cost, schedule, and quality. As one of these changes, the others are impacted. The capture and development of requirements is focused on the quality aspects. Performing requirement analysis in a limited and constrained environment has been show to lead to long term increase schedule, increase cost, and decrease quality. History has also shown this be a significant contributor to product failure.

However working in a limited requirement analysis approach is useful to manage early technical risk and new ideas. In these cases, the limited resources are focused on the high risk aspects to demonstrate feasibility of a new technology, approach, or process. In these cases, the requirement analysis is focus on analysis of the high risk aspects while re-use / off-the-shelf is used elsewhere in the demonstration. Once successful and the decision is to incorporate into a product, then the rigors of requirements management must be applied.

Mike Vinarcik

Lead Senior Systems Engineer at Booz Allen Hamilton and an Adjunct Professor (Systems Architecture and Engineering) at the University of Detroit-Mercy. He has mentored FRC Team 1701, the Robocubs of the University of Detroit Jesuit High School and Academy, for the past four years. He is a past President of the INCOSE Michigan Chapter and operates the Systems Architecture Guild YouTube channel.

FIRST Robotics Competition Strategy

ROBOCUBS

Courtesy of Team 1701:
The RoboCubs

University of Detroit
Jesuit High School
and Academy

Science asks how,
Faith asks why,
We ask both.

www.uofdjesuit.org
www.robocubs.com

What is a System?

It is:

- A collection of parts/components
- The interactions/interdependencies & interfaces

What is a System (Continued)?

The function of the system is greater than the sum of the functions of the individual parts.

- 1+1 = 3 because 1 + 1 + interfaces = 3

- Without the interactions we just have a box of parts that doesn't do anything useful!

How To Succeed

- The first step in succeeding (or winning) is **<u>not to fail</u>**…

- …and the first step to **<u>not failing</u>** is to understand the problem: to "frame" the problem (establish its boundaries)

The Zeroth Law of Engineering

- Zeroth law:
  - Any project must be achievable by the project team, with the skills and resources they have, IN THE TIME AVAILABLE
- Don’t overcomplicate the solution because you need to build it before the competition!!!

101 Things I Learned in Engineering School by John Kuprenas and Matthew Frederick

- 3: The heart of engineering isn’t calculation; it’s problem solving
- 6: “Inside every large problem is a small problem struggling to get out” - Tony Hoare

101 Things I Learned in Engineering School by John Kuprenas and Matthew Frederick

- 97: "The most important thing is to keep the most important thing the most important thing." - Donald P. Coduto, *Foundation Design*
- A laser-like focus on keeping the team on task (and solving the right issues) is how you can improve your odds of winning!

What is Systems Architecture?

- “Systems architecture is the mapping of function to form via concept.”
  - Ed Crawley and Willard Simmons, “Towards a Formalism for System Architecture, from Value to Architecture” (MIT Lecture, 2006)

- So that’s translating WHAT it does into the DESIGN by selecting HOW it will do it.

Example: Writing Instruments

- Function: Make a mark on paper
- Form: Pencil
  - Concept: Wear away a graphite rod via friction with the paper
  - Variations: mechanical, wood
- Form: Pen
  - Concept: Dispense ink
  - Variations: Quill, fountain, ball-point, rollerball

Typical FIRST Robotics Functions

- Collect game piece
- Control game piece
- Align game piece
- Deposit game piece
- Move

(From Jerry Kempf, RoboCubs Mentor 2016)

Your Goal

- You don’t want to build the best robot possible…

- You want to build a robot that can win the competition by:

  - Not being disqualified (instantly losing)
  - Doing its “job” better than the other robots

Your Robot’s Job

- Your robot has one job: to convert time into points

- Time is the primary “currency” you have to spend
- Game pieces are the other

- How your robot “spends” those two commodities will determine how well you do!

Thank you…and good luck!!!

Performing Requirements Analysis in a Limited and Constrained Environment, an Interactive Event Between INCOSE and Indiana FIRST

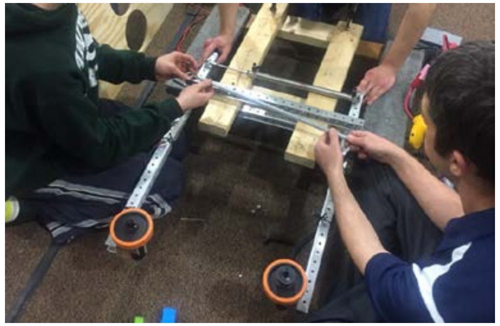
Presented by FRC Team 1024, The Kil-A-Bytes

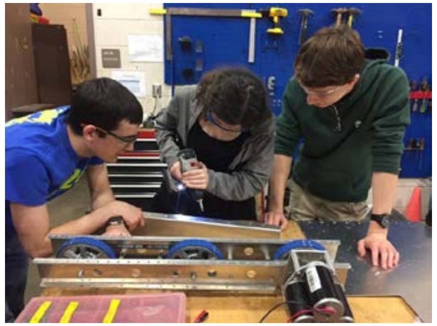
Who are the Kil-A-Bytes?

- About Us
  - We are a high school robotics team from Indianapolis, IN competing in the FIRST Robotics Competition (FRC) since 2003. We are one of thousands of teams worldwide that compete on a local to global level in this annually changing robotics contest.
- 2018 Achievements
  - St. Joseph District Event
    - Event Winner
    - Quality Award
  - Plainfield District Event
    - Imagery Award
  - Indiana State Championship
    - Quality Award
  - FRC World Championships - Detroit
    - Quality Award - Daly/Archimedes Division
  - Indiana Robotics Invitational
    - Event Finalist

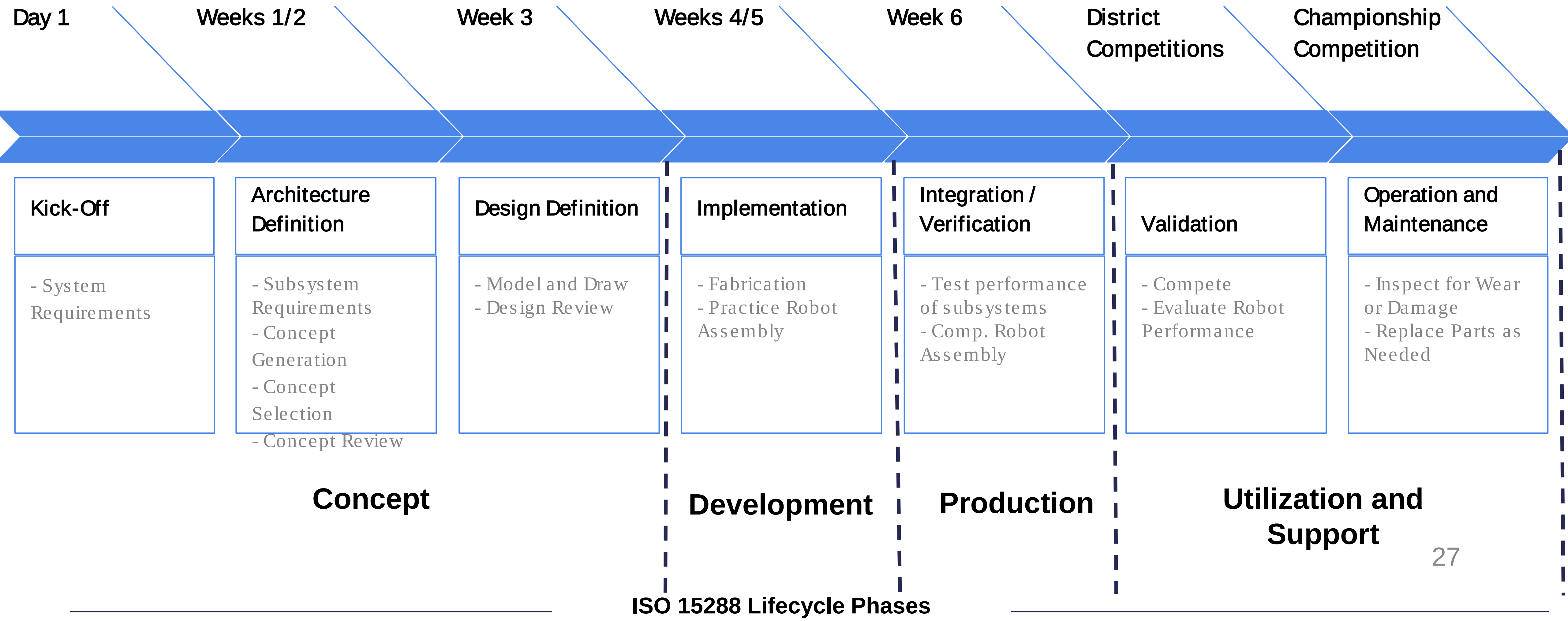
The FIRST Robotics Competition

- The Game Reveal | "Kickoff"
  - Every year, FIRST Robotics reveals a new game via worldwide webcast, kicking off Build Season for every team to design and build their robot in preparation for the competition.
- Build Season | Timeline
  - Build season begins with kickoff in early January and ends in late February after ~6 weeks of hard work. We meet 5 days/week to complete our robot
- Competition Format | Gameplay
  - Teams are pitted against each other in alliances of 3, working together to try and score more points than the opposing alliance.





Kil-A-Byte Design Process



System Requirements Definition

Day 1 - Kickoff

Understanding the Problem

At Kickoff, we are introduced to the game for the first time and are provided a game manual covering all rules of gameplay and robot construction. We spend this first day absorbing this information. To do this we:

- **Read and discuss the game manual**
  - We review the rules as a team to make sure we all are working to the same understanding.
  - Any questions on the rules are recorded for later clarification with FIRST.

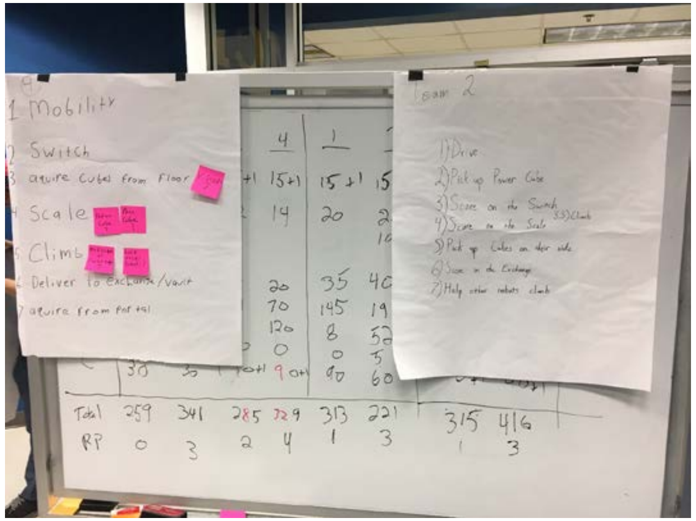
- **Simulate game with human "robots".**
  - Helps identify gaps in our understanding of the game
  - Elicits strategy concepts

Generating Functional Requirements

Our first goal is to determine **WHAT** we think our robot needs to do. We start by:

- **Small group brainstorming**
  - Looking at methods to score points, de-score points, defend, disrupt
  - Create more ideas and strategies based off of others ideas
  - Draw input from all team members
- **Affinitize Ideas Into Functional Groups**
- **Share Results with the full team**

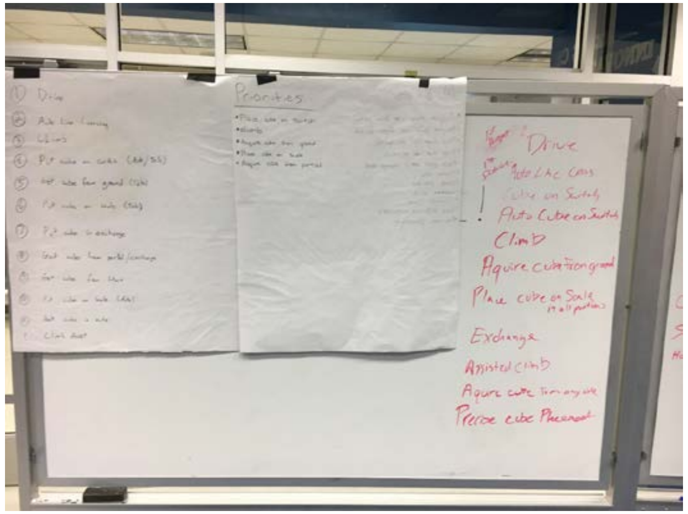
Organizing Potential Functions



Comparing Group Ideas

Defining System Level Requirements

Subsystem
potential priority list



Presenting ideas
to team

- As a team we review the requirements generated in our sub-groups.
- We combine these into a single list of System Requirements for the robot.
- There may be additional requirements for later competitions.

2018 System Requirements List:

- Drive
- Acquire Cube from Ground
- Place Cube on Scale
- Place Cube in Exchange
- Place Cube on Switch
- Climb
- Autonomously Place Cube on Switch

Kil-A-Bytes Requirements Tracker				Master System:	2018 FRC Robot				
				Master Operational Requirement:	To compete in FIRST Power Up				
					Non-Functional Requirements				
ID#	Type	Item	Priority	Requirement	Performance	Implementation	Driver	Owner	Date
1	SYSTEM	ROBOT	MUST	Comply with FRC Rules				TEAM 1024	1/6/18
2	SYSTEM	ROBOT	SHOULD	Meet 1024 Quality Standards				TEAM 1024	1/6/18
3	SYSTEM	ROBOT	SHOULD	Allow for serviceability				TEAM 1024	1/6/18
4	SYSTEM	ROBOT	SHOULD	Utilize controlled failure points where applicable				TEAM 1024	1/6/18
5	SYSTEM	ROBOT	SHOULD	Be documented in accordance with 1024 Engineering Standards				TEAM 1024	1/6/18
6	SYSTEM	ROBOT	SHOULD	Look Good				TEAM 1024	1/6/18
7	FUNCTIONAL	ROBOT	SHALL	Traverse the Arcade				DRIVETRAIN	1/6/18
8	FUNCTIONAL	ROBOT	SHALL	Operate under driver control				CONTROLS	1/6/18
9	FUNCTIONAL	ROBOT	SHALL	Operate under autonoumous control	Auto line, Platform detection, Switch placement, Exchange delivery, Scale placement, acquire second cube			AUTO CODE	1/6/18
10	FUNCTIONAL	ROBOT	SHALL	Climb				CLIMBER	1/6/18
11	FUNCTIONAL	ROBOT	SHALL	Acquire Power Cubes	Rapidly, without regard to orientation, from floor, from exchange, from stack, from portal			ACQUISITION	1/6/18
13	FUNCTIONAL	ROBOT	SHALL	Transport Power Cubes	Securely, max 1			LIFT	1/6/18
14	FUNCTIONAL	ROBOT	SHALL	Orient Power Cubes	Such that a flat side is facing down			ACQUISITION	1/8/18
21	FUNCTIONAL	ROBOT	SHALL	Onboard Compressor				DRIVETRAIN	1/9/18
22	FUNCTIONAL	ROBOT	SHALL	Battery mounting				DRIVETRAIN	1/9/18
54	SYSTEM	ACQUISITION	SHALL	Release Power Cubes to Lift				ACQUISITION	1/16/18

Requirements organized in our 2018 tracking spreadsheet.

Architecture Definition

Weeks 1 and 2

Assign Requirements to Subsystems

- **Define sub-teams needed to meet system requirements**
  - Drivetrain
  - Climber
  - Cube Elevator (Lift)
  - Cube Acquisition
  - Controls

- **Define interface points between subsystems, who will be responsible for what**
  - Attempt to avoid handoff of game pieces between subsystems

- **Sub-teams generate lists of subsystem requirements**

Defining Non-Functional Requirements

- **Define quantifiable performance measures around functional requirements**
  - Prototype concepts to determine what may be feasible
  - Evaluate all steps needed to score points from parked position
    - How long will each step take
    - How long is the entire process
    - Will that be fast enough?

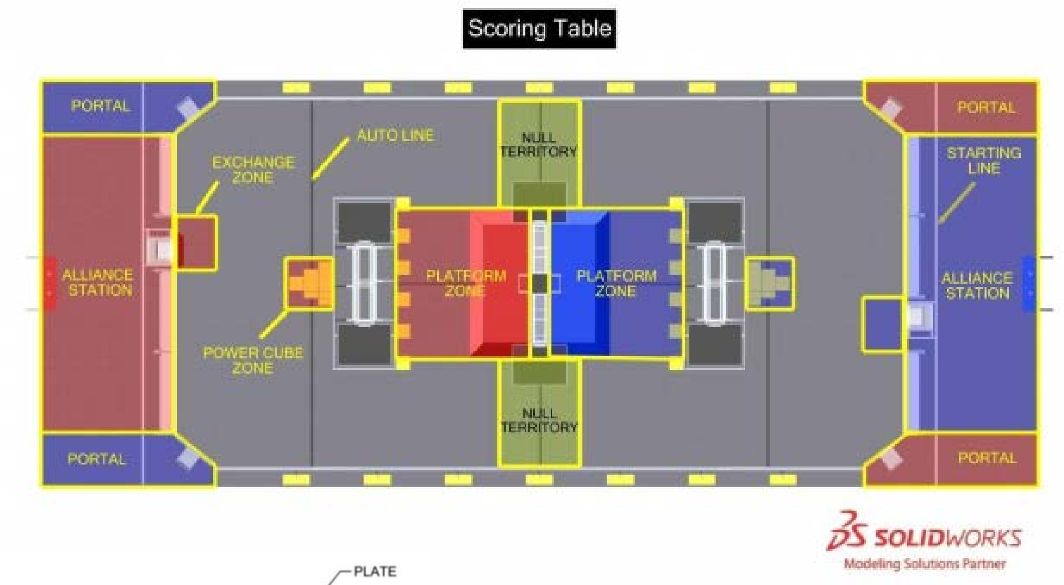
- **Identify implementation requirements imposed by Robot Rules, other subsystems, past experience**

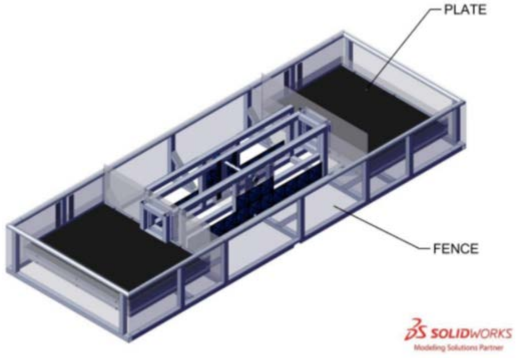
Consider Needs of “Customers” / Stakeholders

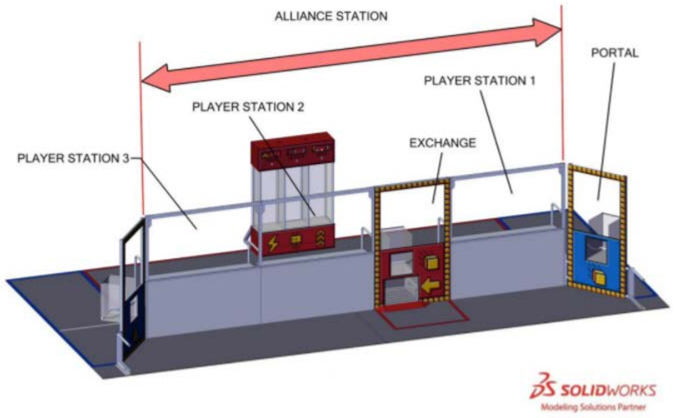
- **Drive Team**
  - Controls robot during matches
  - Works with robot during demos
  - Effectively, the “end users” of our robot
- **Pit Crew**
  - Maintains and regulates the robot.
  - Explains the robots functions to the judges.
- **Judges**
  - Learn about the functions of the robot, as well as the process of its creation
- **Alliance partners**
  - Require our robot to be functional in order to succeed in their competition

2018 Cube Acquisition Subsystem Requirements:

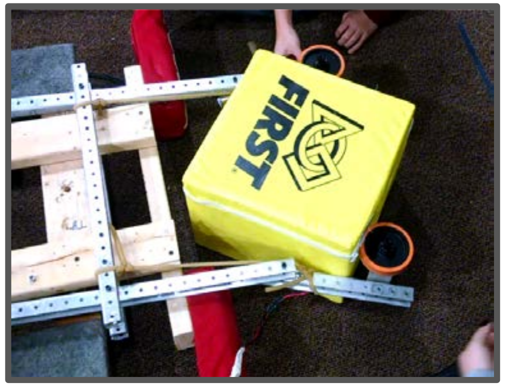
- **Obtain Power Cubes**
  - Acquiring the power cubes from any orientation
  - From floor, exchange, portal or stack
- **Deposit Power Cubes**
  - On switch while in contact with the fence
  - On floor
  - In exchange
- **Orient Power Cube**
  - Such that a flat side is facing down
- **Secure Power Cube**
- **Release Power Cube to Lift subsystem**
- **Collapse within frame perimeter**



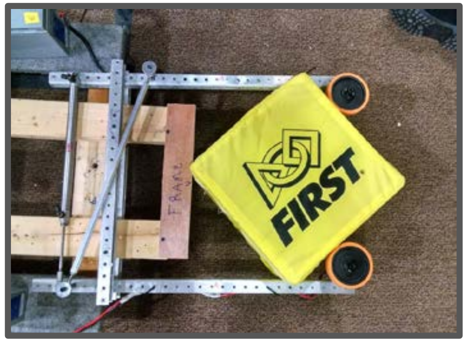




Concept Generation



- After determining the functional requirements, we brainstorm methods for these actions to be carried out while considering possible drawbacks.
- Determine which ideas are unusable, whether due to impracticality or lack of adherence to FIRST regulations, then find new ideas that better conform to those restrictions.
- Create and test versions of these ideas to see how well they work in practice. Revise and improve as needed.



Functions	Means									
Obtain	Horizontal Claw	Vertical Claw	Bucket	Pizza Pan	Horizontal Roller	Vertical Roller	Horizontal Belt	Vertical Belt	Trap	Hook
Orient	Floor	Wrist	Force	Gravity						
Secure	Separate Claw	Compression	Trap							
Deposit	Punch	Release	Reverse Roller	Launch	Reach	Toss				

Function-Means chart used to organize concepts

Concept Selection

- Concepts are chosen by examining the prototype versions of our ideas.
- We measure the performance of each against items on the subsystem requirements list.
- These measures often include:
  - how fast it carries out its intended action
  - the extent to which it can carry out its action (for example, how far an arm can extend)
  - how durable the mechanism is
  - how accurate the mechanism is
- These traits are compared to determine which design best suits our team's needs.
- Trade-offs are made based on what traits the team believes best meet the requirements.

	Weight	**Single Joint Arm**	**Linear Slider**	**4-Bar Arm**
Switch Speed	0.3	0	-1	0
Cube Contact Height	.1	0	-1	0
Agility	.3	0	2	0
Cube Compression	.2	0	1	1
Stack Levels	.1	0	-2	-1
		0	**.2**	**.1**

Pugh Matrix for 2018 Intake Actuation Concepts

Concept Review

Presentation of concepts

- Each sub-team presents the concepts they considered and which one they have chosen to develop.
- Members of each sub-team explain why they chose their concepts and how their requirements will be achieved.
- Team debates and makes a team decision to move forward with a particular concept.

Spreadsheet of Sub-System Requirements

Kil-A-Bytes Requirements Tracker				Master System:	2018 FRC Robot			
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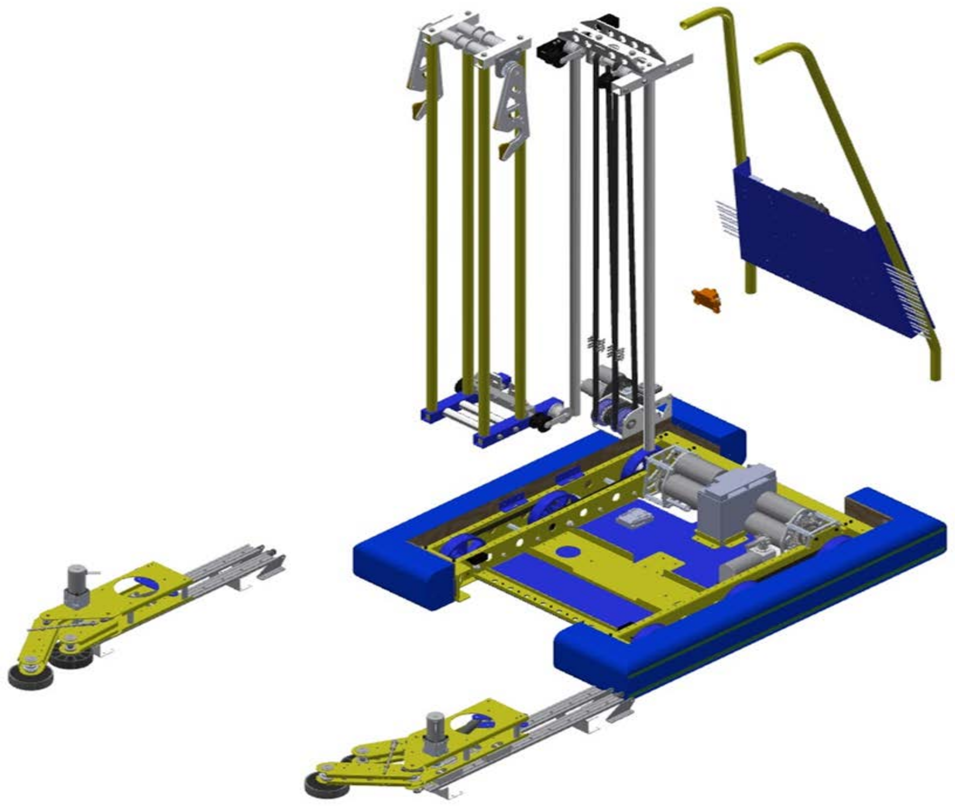
11	FUNCTIONAL	ROBOT	SHALL	Acquire Power Cubes	Rapidly, without regard to orientation, from floor, from exchange, from stack, from portal			ACQUISITION
12	FUNCTIONAL	ACQUISITION	SHALL	Deposit Power Cubes	On switch while in contact with fence, In Exchange, On Floor			ACQUISITION
14	FUNCTIONAL	ROBOT	SHALL	Orient Power Cubes	Such that a flat side is facing down			ACQUISITION
15	SYSTEM	ACQUISITION	SHALL	Secure Power Cubes				ACQUISITION
54	SYSTEM	ACQUISITION	SHALL	Release Power Cubes to Lift				ACQUISITION
55	SYSTEM	ACQUISITION	SHALL	Collapse to within Frame Perimeter			1	ACQUISITION
56	FUNCTIONAL	ACQUISITION	SHALL	Eject Power Cubes onto Switch	When in contact with Fence		12	ACQUISITION

Design Definition

Week 3

Design Review

- **Subsystem teams complete CAD models and drawings of all parts.**
- **Purchased parts are selected and ordered.**
- **Each subsystem team gives a presentation on the parts of the robot they have designed and what they intend to build.**
  - Each sub-team explains how they intend to meet requirements and why they believe the design is realistic and achievable.
  - Any risks or shortfalls to the requirements are identified
  - Anyone can voice their concerns involving the design of the robot.



Complete exploded CAD model

Implementation

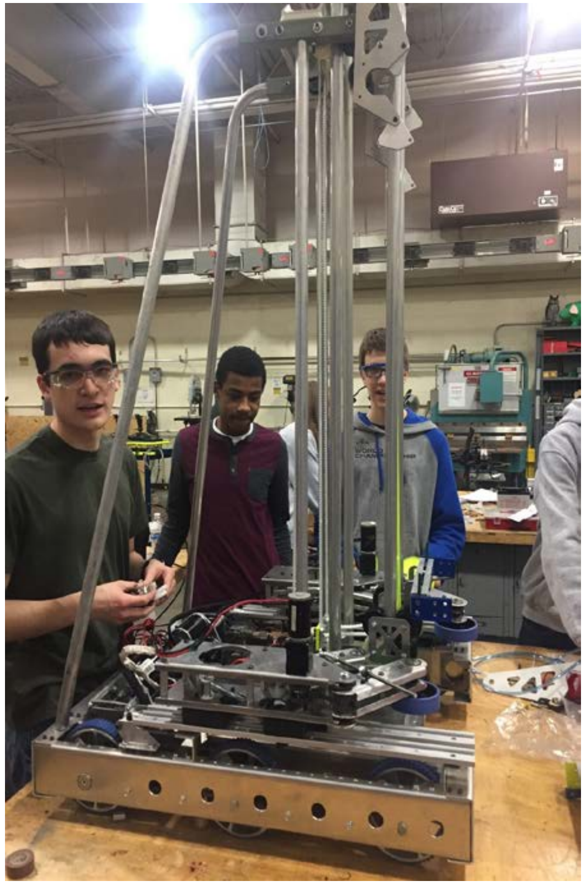
Weeks 4 and 5

Fabrication and Assembly

- CAD files sent to sponsors for laser / waterjet cutting, other parts produced by the team in our shop.
- Assemble robot in sections then put together final assembly.
  - chassis, lift, cube acquisition
- Practice robot used to test and modify assemblies to be implemented on competition robot.
  - Driver and programming practice
- Parts for competition robot sent to sponsors for powder coat and anodizing

Assembly of practice robot acquisition arms

Assembled practice robot



Verification

Week 6

Practice Robot Testing

- Code is loaded to the assembled practice robot and systems are tested together for the first time.
- **Goal**: Find whatever problems possible early on so as to minimize the potential problems at the competition.
- The practice robot also serves as our test bed for future improvements, and allows us to save the competition robot from additional wear.

Competition Robot Assembly

Validation

District Competition

District Competitions

- **We typically choose at least 2 of the 3 Indiana district-level competitions to attend.**

- **At these competitions we:**
  - Get a chance to see how well our robot performs against other robots
  - See where our robot works well and where it needs improvement
  - Figure out priorities and goals to achieve before next competition
  - Attempt to qualify for the State Championship

Implement Improvements

- We develop improvements by looking at the areas where our robot is underperforming.
- A major aid to determining where we can improve is by reviewing data collected from team members who scout every match at competition.
- Also, some team members think of improvements that don’t necessarily fix a flaw, so much as improve a functioning system.
- Improvements are designed similarly to pre-existing features, and go through the same design process.

Operation and Maintenance

Championship Competition

Keeping Everything Working

- **Pit Crew** - Carefully maintains the robot at competitions.
  - Installing upgrade components developed between events
  - Inspecting every part of robot after each match
  - Performing routine systems check of the robot before each match
  - Coordinating closely with the drive team to make sure the robot is ready when needed

- **Scouting Team** - Provides strategic data to the drivers for each match.
  - Watch every match and record points scored by each robot
  - Note strengths and weaknesses of opponents.
  - Data is used to guide our strategy for each match and gauge the performance of our robot relative to others

- **Drive Team** - Wins matches

Thank You

Come see us and other Indiana FIRST teams at these events in 2019!

2019 Indiana *FIRST* Robotics Competition Events		
Week 2 INF District – St. Joseph Event	March 9^{th} – 10^{th} Saturday & Sunday	Penn High School 56100 N Bittersweet Road, Mishawaka, IN 46545
Week 4 INF District – Tippecanoe Event (NEW VENUE)	March 23^{rd} – 24^{th} Saturday & Sunday	Jefferson High School 1801 S. 18^{th} St, Lafayette, IN 47905
Week 5 INF District - Center Grove Event (NEW VENUE)	March 29^{th} – 30^{th} Friday & Saturday	Center Grove High School 2717 S. Morgantown Rd, Greenwood, IN 46143
Week 7 FRC® Indiana State Championship	April 12^{th} – 13^{th} Friday & Saturday	Kokomo Memorial Gym 5 E. Superior St, Kokomo, IN 46901
Visit the IndianaFIRST Event Page for more details! http://www.indianafirst.org/calendar/		

GLRC 2018

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www.incose.org/glrc2018