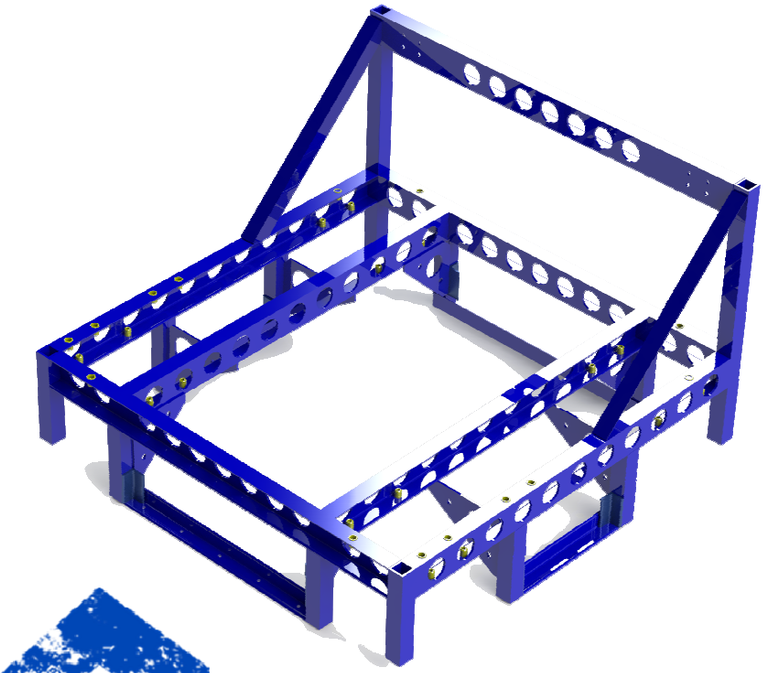
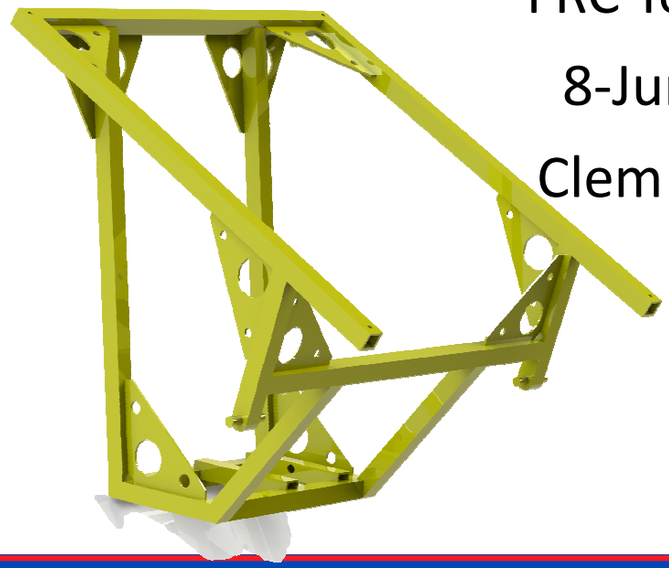
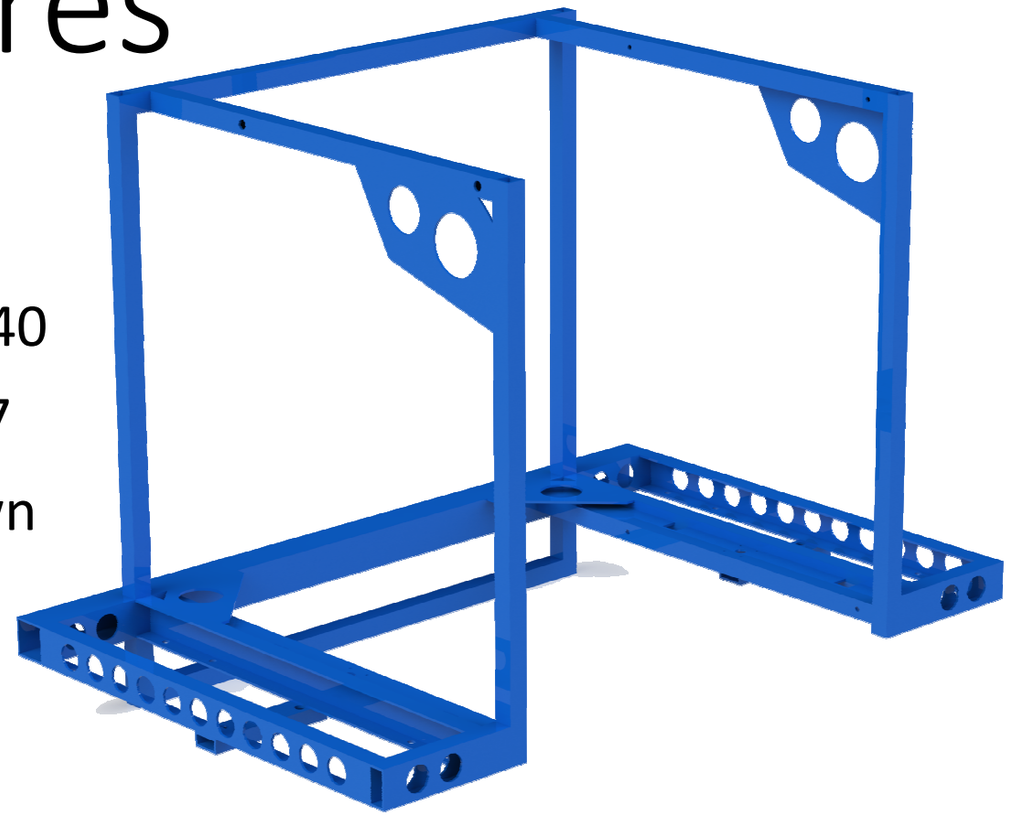


Structures





FRC Team 1640

8-June-2017

Clem McKown

What structures do

- Structures hold the robot's mechanisms and other parts in their correct positions and orientations relative to each other
- Provides the structural strength necessary to hold the robot together during competition
- Anchors and supports all components (directly or indirectly)
- A robot may contain multiple structures
- Those multiple structures may articulate (rotate, extend or otherwise translate) in relation to each other; but
- An individual structure is not articulated

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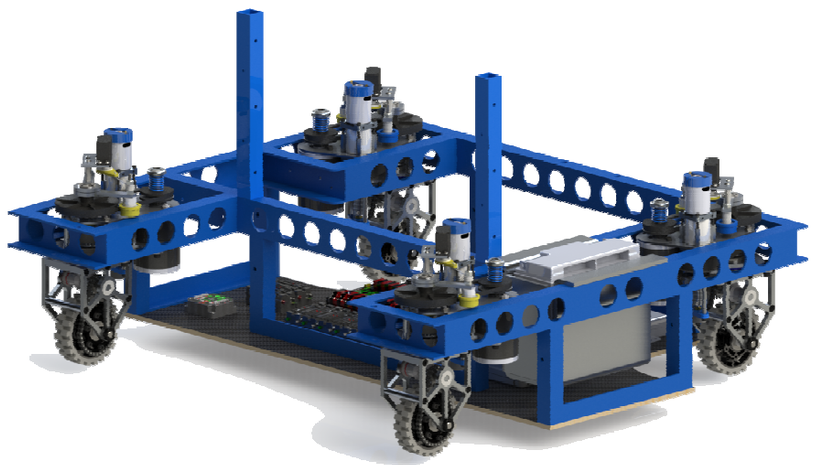
Chasses

- If your robot has one structure, it’s the chassis
- The chassis connects directly to the drive-train or drive-train components
- The chassis also provides mounting points for all fixed and articulated systems

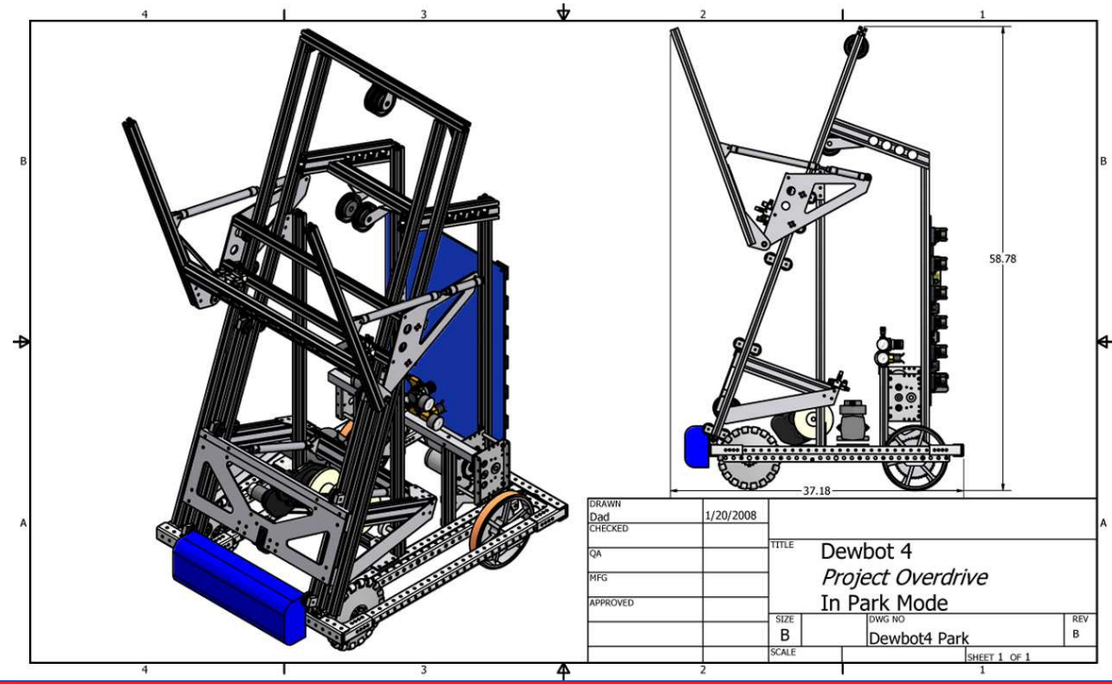


Chassis/Structure constructions

- Kit-Bot
- Extrusion System (e.g. 80/20)
- Bolted Frame
- Welded Frame
- Monocoque
- Other

Kit-Bot

- AndyMark provides extruded Al frames suitable to tank-drive robots
- Part of the Kit-of-Parts unless you opt out
- Includes basic drive-train
- Easy
- Economical
- DEWBOTS I, II & IV used this



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Extrusion Systems

- Extruded Al systems are available for assembling custom structures
  - 80/20
  - Rev Robotics
  - Others
- Rigid for the weight
- A variety of connection options available
- Linear articulation is straight-forward

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Bolted/Riveted Frames

- Designed chassis with custom designed elements – bolted or riveted together

Welded Frames

- Welding offers weight savings and simplified design
- Complicates field repairs
- Want a basically finished design before you start fabrication
- FRC 1640 has used welded chasses since DEWBOT V (2009, *Lunacy*)
- 6061 Al is used for welded chasses (6063 weldable, but weaker)
- Welding Aluminum requires inert atmosphere (Argon). MIG (Metal Inert Gas) or TIG (Tungsten Inert Gas) welding. We use MIG.
- Welding introduces mechanical distortion. Needs to be accounted for in design.
- Weld bead generally extends from the work surface, so joint areas are not flush; grinding can provide a flush surface, but this needs to be noted in welding instructions

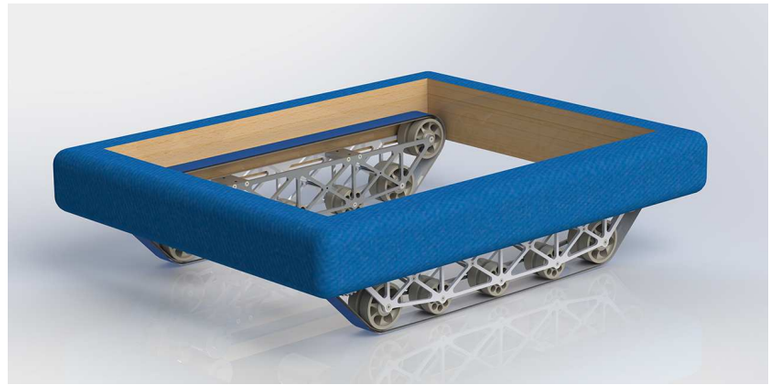
Monocoque

- Formed sheet metal forms the main structural elements, reducing or eliminating the requirements for extruded structural elements.
- 1640 does not have these capabilities, or the necessary design skills.

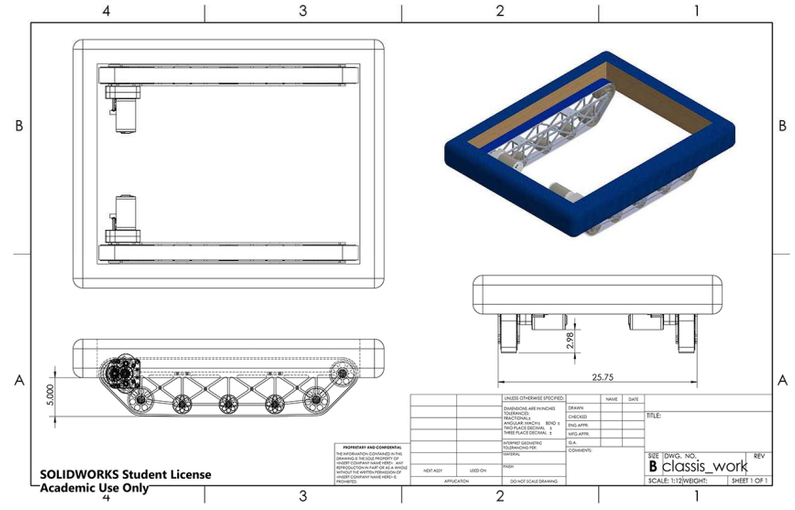
Design Process Thoughts

- Understand where your main systems and components need (or ought) to be first.
- Lay them out in space (CAD is good for this).

DB 11 was largely designed around the stack of totes it needed to build and transport to score.



DB 12 drive-train and bumpers in place in space. This starts to define the chassis. Critical dimensions are in drawing.



Good Practices

- A closed polygon is stronger than an open structure
- Sharp joints are stress concentrators – gussets distribute stress, stiffen joints and reduce the prospect of frame failure
- Bolting through a tube or channel will cause the tube to collapse when the bolt is tightened – the bolt will never be tight
- Think of maintenance – provide access to tighten or loosen fasteners
- Think of maintenance – use rivet nuts to ease fastener access
  - Also tapped holes – but remember these threads are inherently fragile
- *GAME DEMANDS RULE!*

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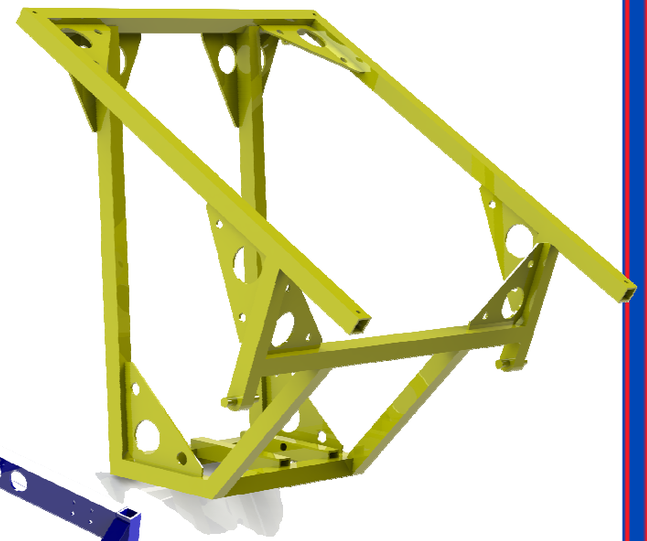
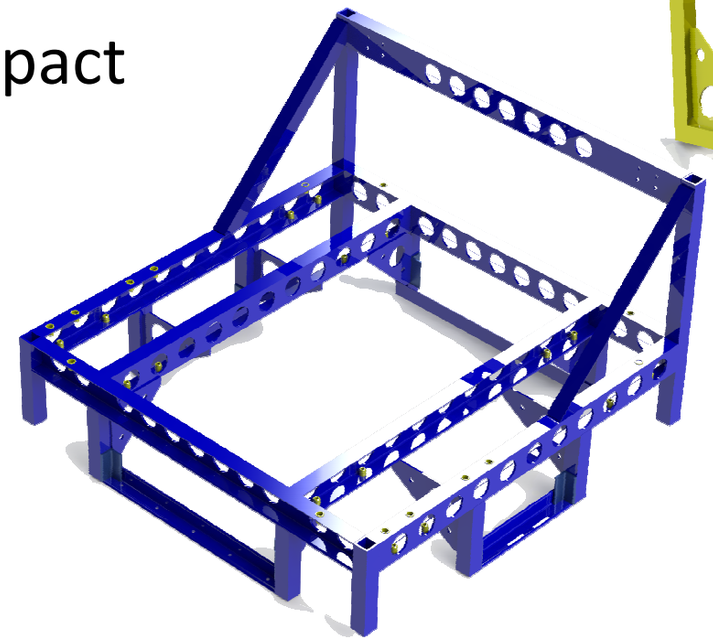
Dewbot X

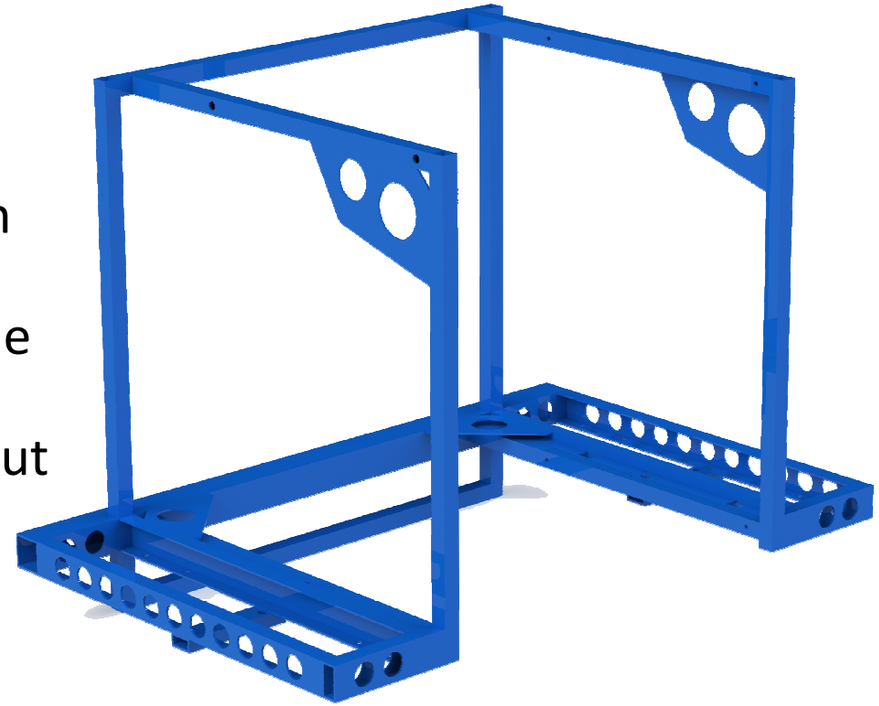
- A closed polygon is stronger than an open structure
- Dewbot X had two major welded structures – both closed polygons – both heavily gusseted
- Game was extremely high impact
- Robot very successful





Dewbot XI

- A closed polygon is stronger than an open structure …but…
- Dewbot XI had a U-shaped chassis with an entirely open front
- Critical need from a game standpoint
  - Needed to build a stack of 6 totes with a recycling can on top and put a pool noodle in the can (55.7 lb_m)
  - This (center of) mass needed to be well inside the wheelbase
  - Chassis needs to support a lot of mass without excessive deformation
- Mitigating strategies were used
- Game had low impact potential
- Robot very successful



Color

- Painted or anodized chassis makes a robot look better. More finished and professional.
- Better looking, finished and professional looking robots are more likely to be picked for alliances, other factors being roughly equal.
- FRC 1640 paints chasses with spray paint. Blue & Yellow.
- Powder coat & cured coatings are more durable. Requires professional application. Takes more preparation and time. Also more cost.
- Anodized coatings are harder (they are ceramic: Al_2O_3). Also professional application.

Fasteners

- Bolts
- Nuts
- Rivets
- Welding
- Soldering/Brazing
- Adhesives

Bolts

- The team uses inch-size hex-socket screws
  - Mostly #4-40 through ¼”-20 but on occasion up to ½”
  - Standard thread except #10 (use 10-32)
  - 10-32 is our most common bolt size, followed by ¼”-20
  - Some metric bolts due to OEM requirements
- Socket Head Cap Screws
- Button Head Cap Screws
- Flat Head Cap Screws
  - FHCSs must be countersunk

- When appropriate, we use shoulder bolts and eye bolts
- Bolts are specified by type, diameter, thread count and length. For bolts longer than 1”, it’s important to know if fully threaded

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Nuts

- Nylok Nuts are the team standard
  - Because they don’t come loose and fall off
  - But Nyloks < ¼” are low-strength
- Also use normal Hex Nuts
- Tapping is used as an alternative to nuts, but is weaker and prone to damage, as most tapping is done into Aluminum or polymers
- Rivet Nuts provide fixed nuts swaged in place on a structure

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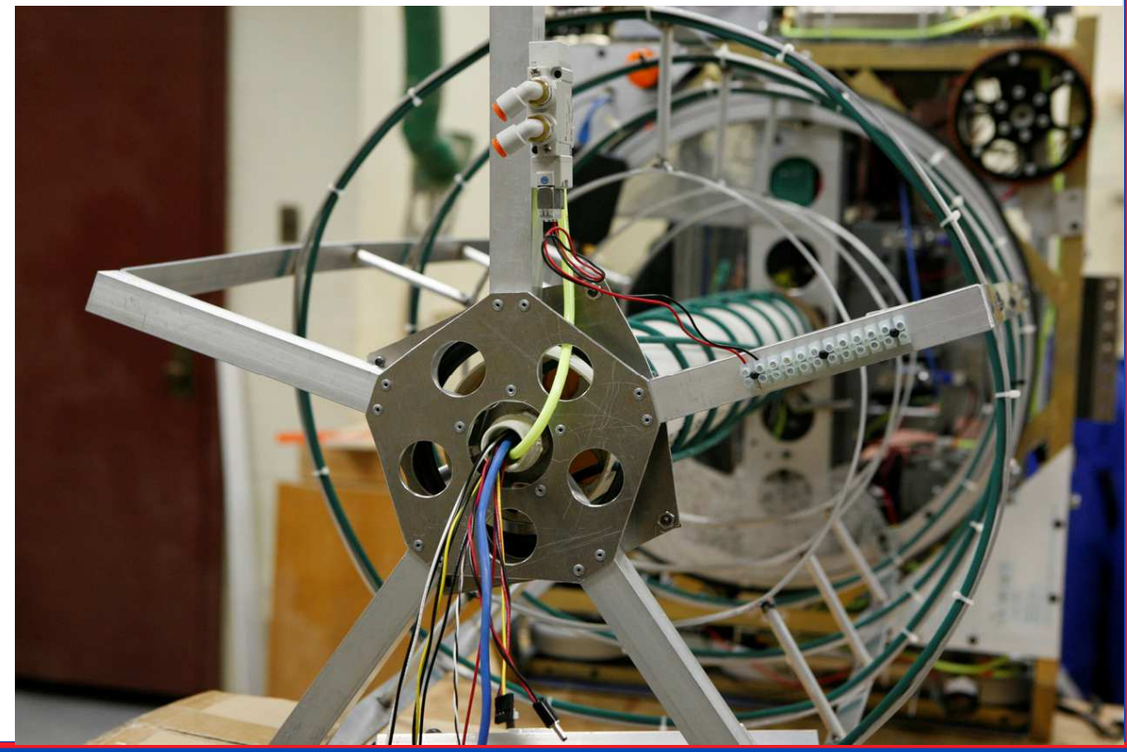
Rivets

- Pop rivets provide fast, lightweight connections
- Particularly good for blind fastening
- Steel & Al rivets available
- Washers needed for polymers
- Tendency to loosen over time
- Can be drilled out to remove



Fusion Welding

- Uses heat to melt metal in order to join two pieces of metal together
- To be effective, both pieces of work, together with the welding wire, need to melt and flow together form a solution, which solidifies to form a fused piece via a solid solution
- Welding dissimilar metals in not generally possible
- Not all Aluminum alloys are suited to welding. 6061 & 6063 are. 7075 is not
- Aluminum must be welded under inert (Ar) atmosphere, as Al_2O_3 forms rapidly in contact with O_2.
- Welding eliminates benefits of heat strengthening in weld areas. Assume 40% strength reduction in the weld locality. This needs to ba taken into account. Can be restored through further heat treatment.

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Brazing

- Soldering forms a metal connection between two metal parts by melting a low-melting-point dissimilar metal onto the joint area and allowing it to cool.
- Molten solder must wet both surfaces to be joined
- Solder can join dissimilar surfaces, as long as it is able to wet both
- The joint formed is mechanical with van der Waal's force providing adhesion – there is no solid solution of joined materials
- Weaker than welding
- Very effective (as soldering) for reliable electrical connections

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Adhesives

- Adhesives are used to create structural bonds between metals
- Adhesives are used to bond Aluminum for both aircraft and bicycle frames
- Epoxies are generally used for high-strength adhesive bonds

An important note on fasteners

- Fasteners are important aspects of mechanical design
- Fastener design/specification is an important aspect of design
- The fasteners needed for a structure and mechanism need to be fully specified and the fasteners needed must be communicated clearly to team procurement
- During 2017 build season, we were caught with our pants down repeatedly by not having the fasteners we needed when assembling designed systems; the assumption was made that we would have the needed fasteners in-stock. Bad assumption.
- The team stocks fasteners based on past design requirements and purchases.

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