US Air Force
Satellite Thermal Cycling
ARIZ Analysis

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2016

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Presentation Content

- Portions of an ARIZ analysis for the Air Force Satellite Thermal Cycling project
- Some solutions are restricted from distribution
- Overall problem solving path way and direction shared
- Variety of solution discussed

Problem Statement

- There is a satellite system where precise system tracking, control and sensing is in turn depending upon the fixed and constant relationship between various components mounted (mechanically attached - i.e., bolted) on the exterior of the satellite. More specifically the relationship between the sensors that track the satellite's position, measure the satellite's orientation and that sense and gather extra-system data must have a constant three-axis relationship to each other. In the system the components are mounted (bolted) on a static graphite honeycomb structure referred to as a top deck. The satellite moves in and out of the solar radiation field as the satellite orbits the earth. The system works well but does experience slight relative component reorientation as thermal stresses change the graphite honeycomb ($\alpha = 6.35X10^{-5}$ mm/mm/C°) top deck "static" geometry. This slight cyclical change, driven by orbital thermal cycling, to the top deck's "static" geometry slightly reorients the relative position of the top deck components during the orbits. This thermal cycling of the top deck causes slight sensor alignment issues which can reduce orientation and tracking accuracy. The goal of the project is to innovate methods to reduce or eliminate the effect of top deck thermal cycling on the relative position of the components.

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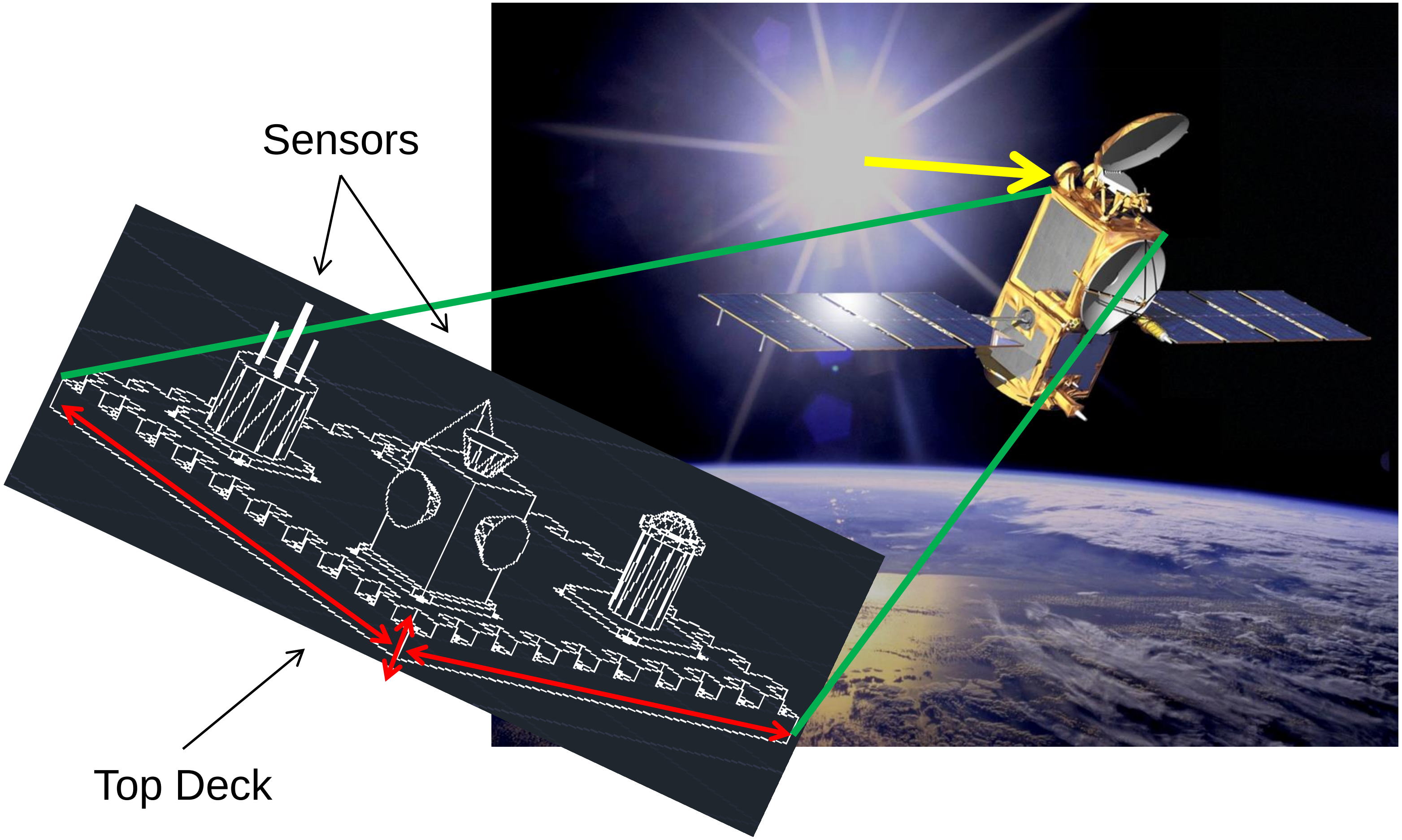
Satellite Thermal Cycling

Satellite Thermal Cycling



Part 1. Problem Model

- **Part 1. Problem Model**
  - There is a graphite honeycomb structure (top deck) on the exterior of a satellite that is used to support and orient the various sensor tools that support the basic and auxiliary functionality of the satellite.

    Top Deck *holds* Sensors
- That consists of (list major parts):

    satellite body, satellite electronics, top deck, sensors
- Engineering contradiction 1:

  EC-1: If the Top Deck is one continuous piece then the relative position of the sensing components are set but thermal cycling (static shape change) will change those relative positions
- Engineering contradiction 2:

  EC-2: If the Top Deck is not one continuous piece then the relative positions of the sensing components will be more difficult to set but thermal cycling (static shape change) will not change those relative positions

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Part 1. Problem Model

- It is necessary to have a Top Deck which allows the fixing of the relative positions of the sensing components and does not allow the relative positioning to change without making the system more complex, with minimal changes to the system, and without any harmful effects.

1.2 To define the tool and the product

- **Tool: Top Deck**

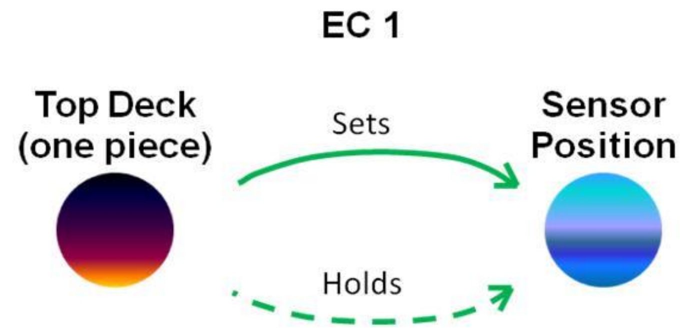
  State 1 - one static piece

  State 2 - multi-pieces / dynamic pieces

- **Product: Sensors**

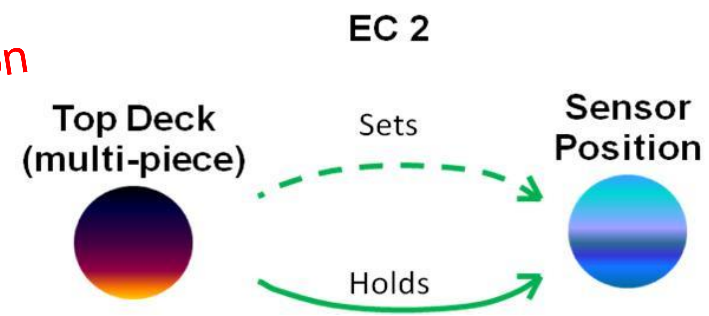
Part 1. Problem Model

1.3 Graphic presentation of EC-1 and EC-2



- EC 1 - One piece Top Deck does a good job establishing the relative positions of the sensors but does not hold that relative position during operation due to thermal cycling

EC 2 was used as the basic engineering contradiction



- EC 2 - Multi- piece Top Deck makes it more difficult to establish the relative positions of the sensors but does not cause relative movement of the mounted instruments due to thermal cycling

Product – Sensors
Tool – Multi-Piece Top Deck

1.5 The aggravated basic contradiction

A non existing Top Deck cannot displace the sensors during thermal cycling but it is impossible to mount the sensors in the first place.

1.6 There are (to indicate the product and the tool from step 1.4 under the condition of step 1.5)

It is necessary to introduce an x-component that will enable a *nonexistent Top Deck* that does not displace the sensors during operation and allows precise mounting of the sensors

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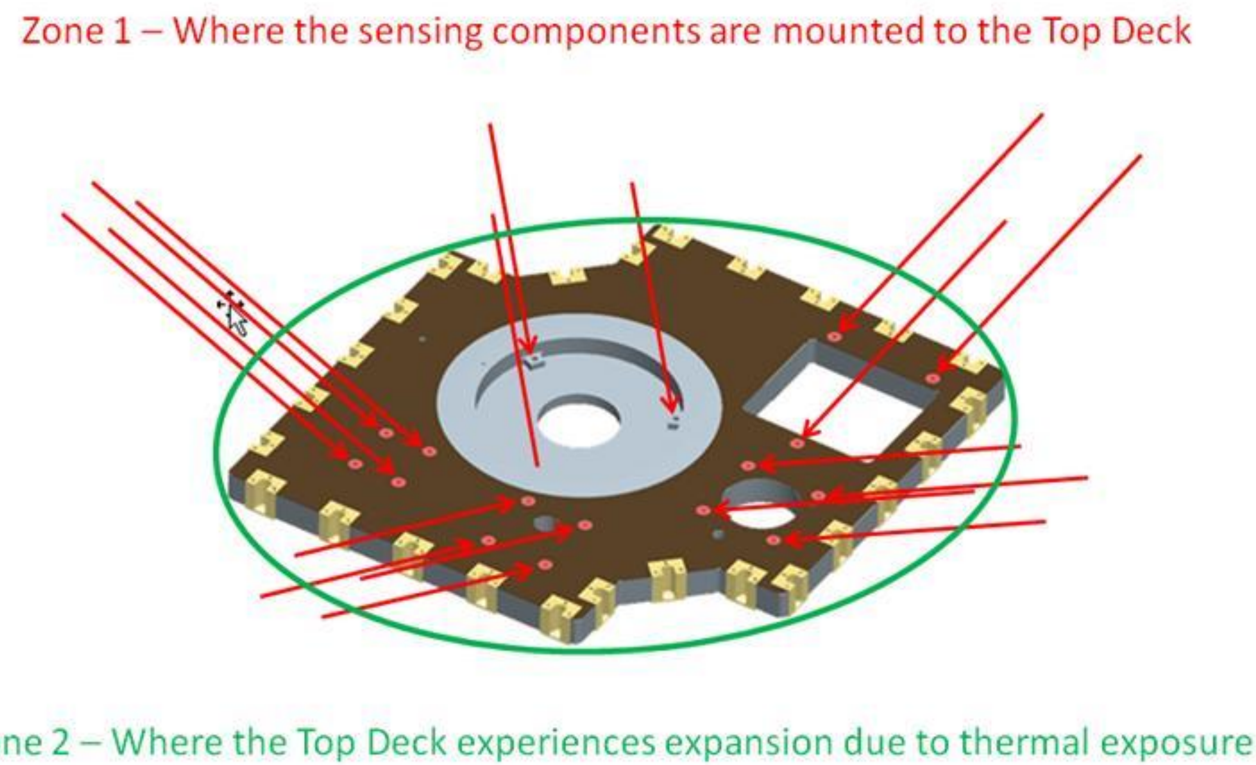
Part 2. Analysis of the Problem Model

2.1 To define the operating space (the space where there is a conflict)

The operating space is the non-existing Top Deck and sensing component interfaces



Do the zones overlap? Yes – therefore it is not obvious how to solve this problem using separation in space strategies

Part 2. Analysis of the Problem Model

2.2 To define the operating time (T = T1 + T2 + T3)

Are the Sensing Component Alignment and the Displacement of the Sensing Components Simultaneously? No – therefore it is advisable to explore separation in time principles

Do we have T1 (time before the conflict) to improve the situation in advance?

Yes – for example – eliminate the surfaces capable of capturing solar radiation or shape those areas to stop the solar radiation

Do we have T2 (time during the conflict) to improve the situation during the conflict?

Yes – for example – design "floating" component mounts

Do we have time T3 (time after the conflict) to correct the situation?

Yes – for example - design components that understand their orientation in relation to each other and correct their telemetry calculations accordingly

2.3. Substances and fields resources analyse in the operating space:

	Substance	Parameter	Field
Tool	1.) Top Deck	a.) Shape	Mechanical
		b.) Size	Mechanical
		c.) Elec. Resistance	Electro-magnetic
		d.) Elec. Conductivity	Electro-magnetic
		e.) Thermal Conductivity	Thermal
		f.) Thermal Resistance	Thermal
		g.) Emissivity	Electro-magnetic
		h.) porosity	Mechanical
		i.) Magnetism	Electro-magnetic
		j.) Coeff. Of Thermal Exp.	Mechanical
		k.) Reflectivity	Electro-magnetic
		l.) Malleability	Mechanical
Product	2.) Sensors	....	....
Others categories	3.) Satellite Body		
	4.) Comm./Electronics		
	5.) Signal Power		
	6.) etc.		

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Part 3. Ideal final result and physical conflict

3.1. Define IFR:

X-Component eliminates the displacement of the sensors during operational thermal cycling and allows for the precise mounting of the sensors on the satellite "top deck" during satellite construction at the sensing component / satellite interface zone without making the system more complex and without any harmful consequences.

3.2. IT is NOT allowed to use foreign, new fields and substances

Substitute X-component for all the SFRs defined at step 2.3 – for example:

Top Deck eliminates the displacement of the sensors during operational thermal cycling and allows for the precise mounting of the sensors on the satellite "top deck" during satellite construction at the sensing component / satellite interface zone without making the system more complex and without any harmful consequences.

Sensor eliminates the displacement of the sensors during operational thermal cycling and allows for the precise mounting of the sensors on the satellite "top deck" during satellite construction at the sensing component / satellite interface zone without making the system more complex and without any harmful consequences.

etc.

3.3. To define the physical contradiction on macro level – for example:

The Shape of the Top Deck should be thin to eliminate the sensor displacement due to thermal cycling and/or wide to allow accurate mounting of the sensors.

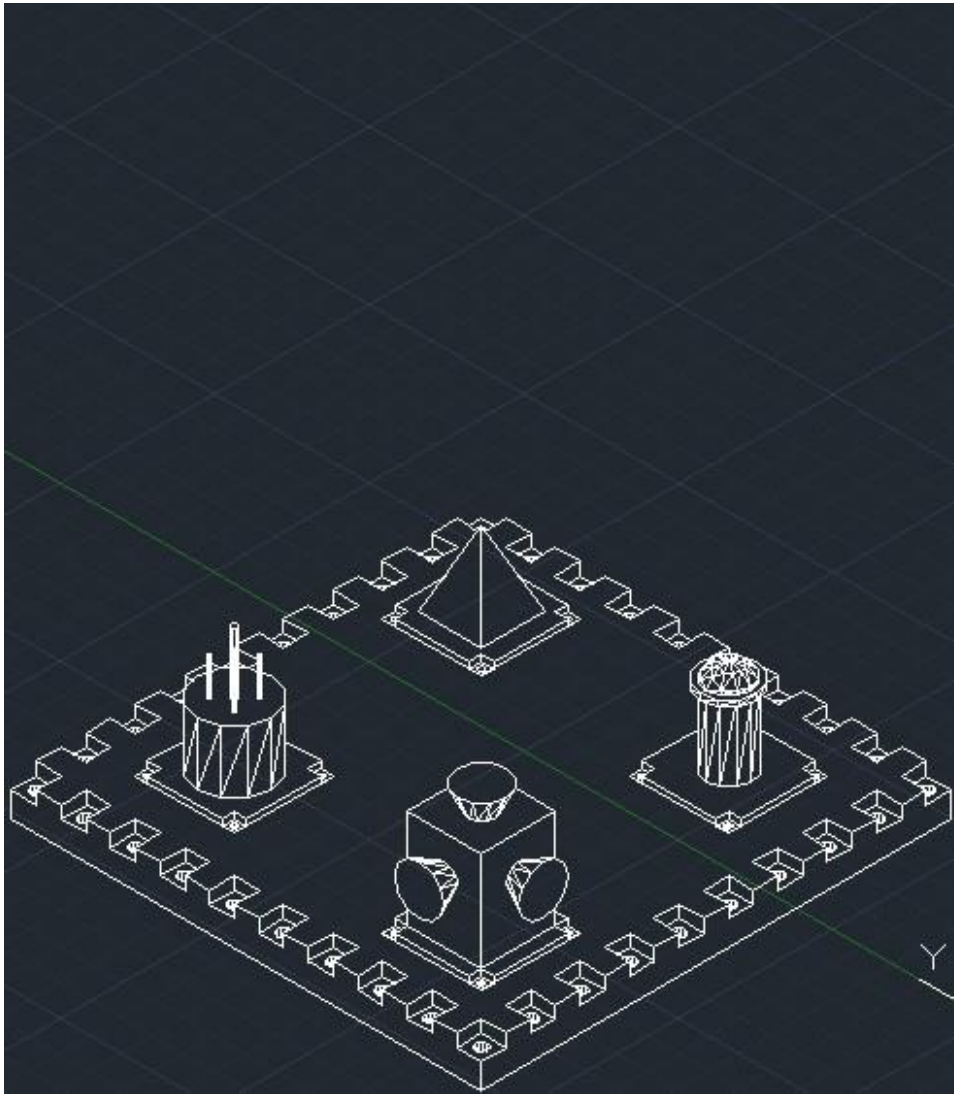
Solution concept –

Sensors attached on top portion of "cooling fin" array that effectively move all sensors in unison along the Z axis resulting in no relative displacement

etc.

Part 3. Ideal final result and physical conflict

Sensors attached on top portion of "cooling fin" array that effectively move all sensors in unison along the Z axis resulting in no relative displacement



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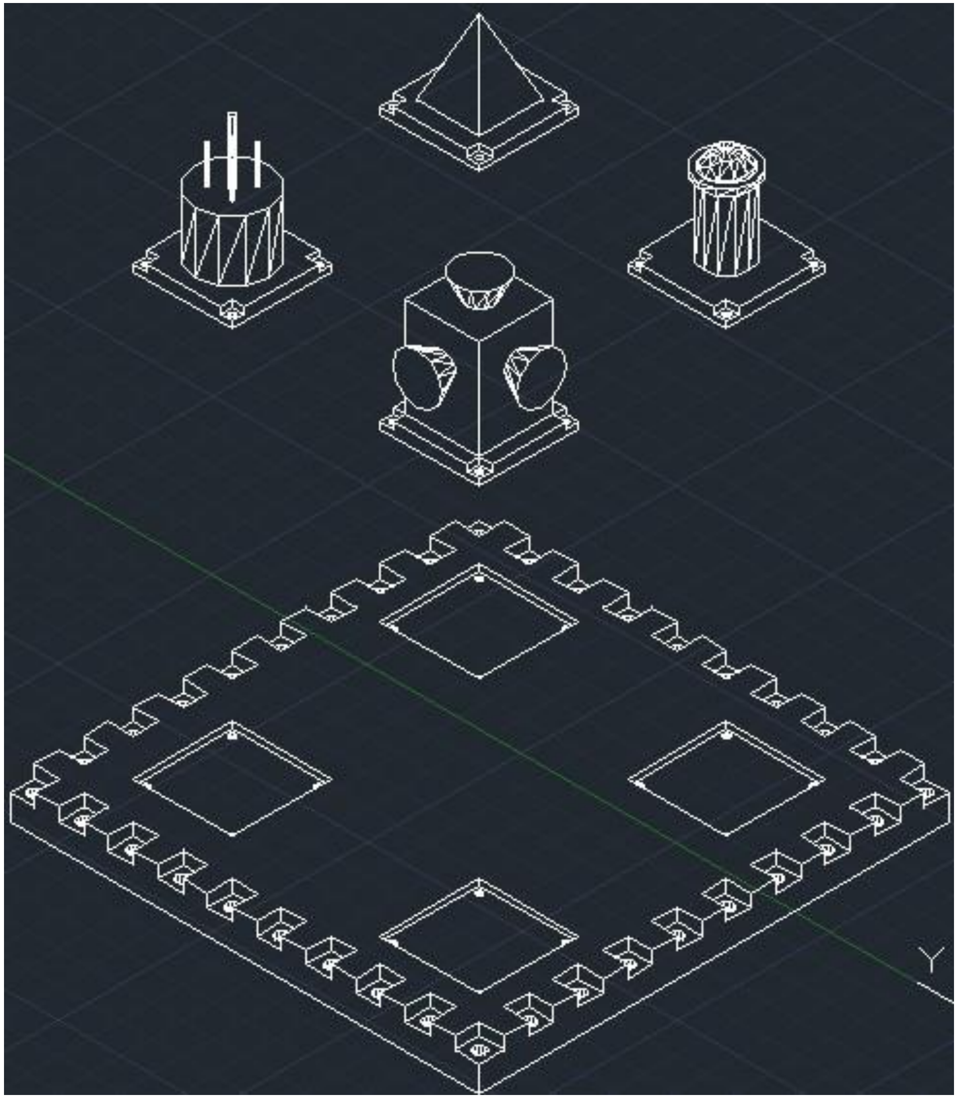

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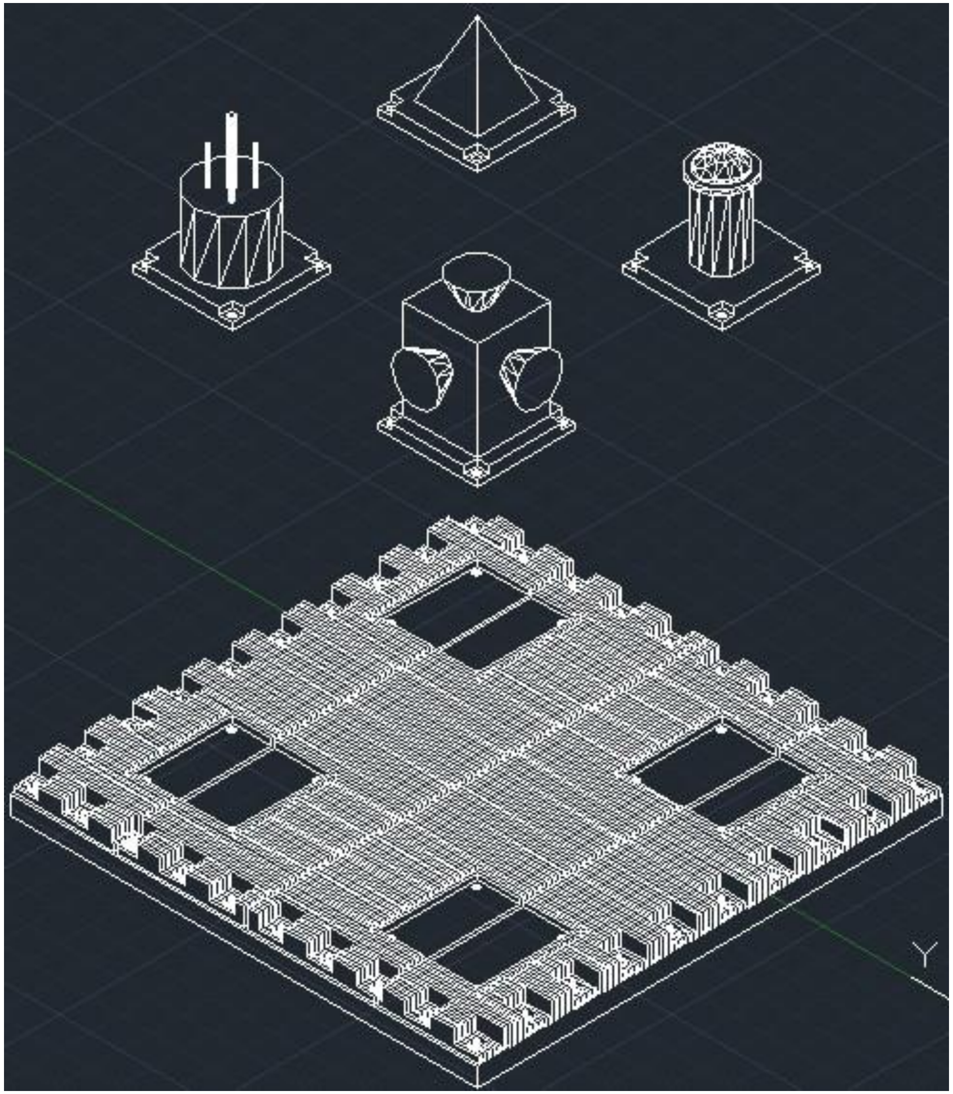

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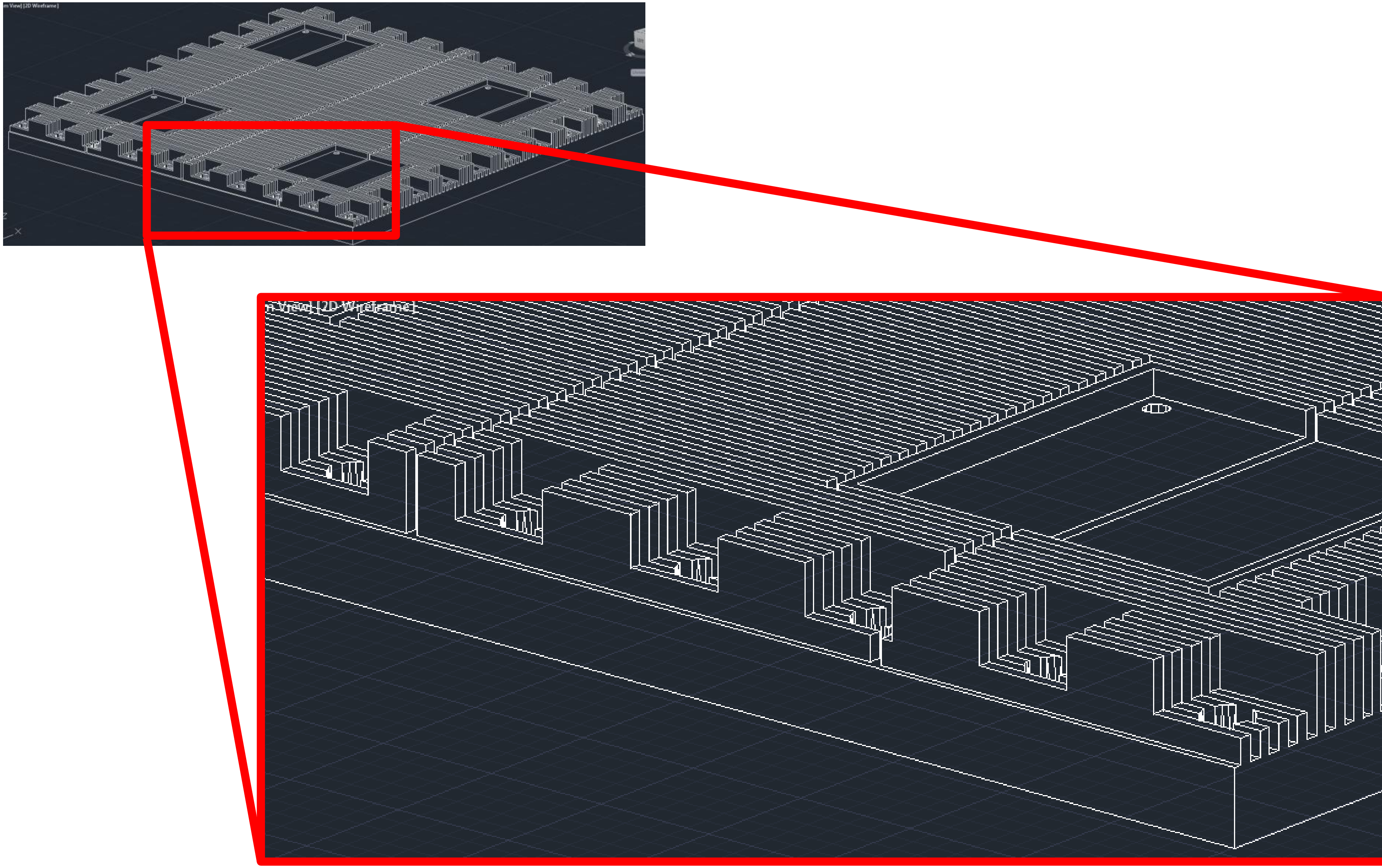
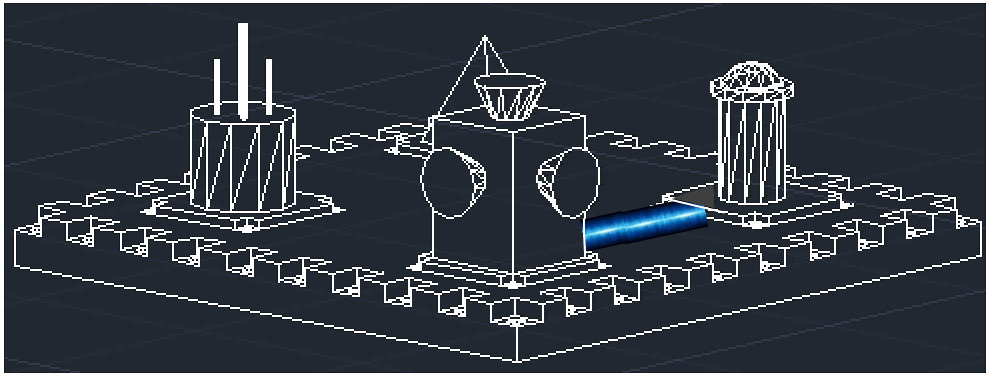


3.3. To define the physical contradiction on macro level – for example:

The Wavelength of the Sound should be ? to eliminate the sensor displacement due to thermal cycling and/or ? to allow accurate mounting of the sensors. *Note – if a necessary change in the analyzed parameter can not be determined then try to solve the problem in a single state of the parameter*

Solution concept –

Bounce sound waves in-between the sensor bases (interior or exterior of the Top Deck) to measure relative positions of sensors and adjust operations coordination accordingly



3.5. Develop macro level contradiction solutions:

Index		Top Deck ARIZ Part 3.xls							
Section Three - resolve Physical Contradiction (see "solution concepts" sheet for solutions)									
				Separation					
		X-Component	Parameter	Space	Time	Relation	Super, Sub Transition	Satisfaction	By Pass
1	a	Top Deck	**a.) Shape**	n/a	n/a	relation	n/a	n/a	n/a
1	b	Top Deck	**b.) Size**	n/a	n/a	relation	n/a	n/a	n/a
1	h	Top Deck	**h.) Porosity**	n/a	n/a	relation	n/a	n/a	n/a
1	m	Top Deck	**m.) Composition**	n/a	time	n/a	n/a	n/a	n/a
2	a	Sensors	**a.) Shape**	n/a	n/a	relation	n/a	n/a	n/a
2	l	Sensors	**l.) Malleability**	n/a	time	n/a	n/a	n/a	n/a
2	m	Sensors	**m.) Composition**	space	n/a	n/a	n/a	n/a	n/a
3	b	Satelite Body	**b.) Shape**	n/a	n/a	relation	n/a	n/a	n/a
3	c	Satelite Body	**c.) Size**	n/a	n/a	relation	n/a	n/a	n/a
Micro		Top Deck Latice Particles	Mobility	n/a	time	n/a	n/a	n/a	n/a

For Example:

Physical Contradiction 1M - Separation in Time

Principle 15. Dynamics

Principle 11. Beforehand Cushioning

Top Deck (or Sensor bases) have pneumatic or hydraulic structures which push sensors in opposite direction of top deck movement utilizing the same solar radiation to affect the structure internal pressure and therefore “opposite” movement

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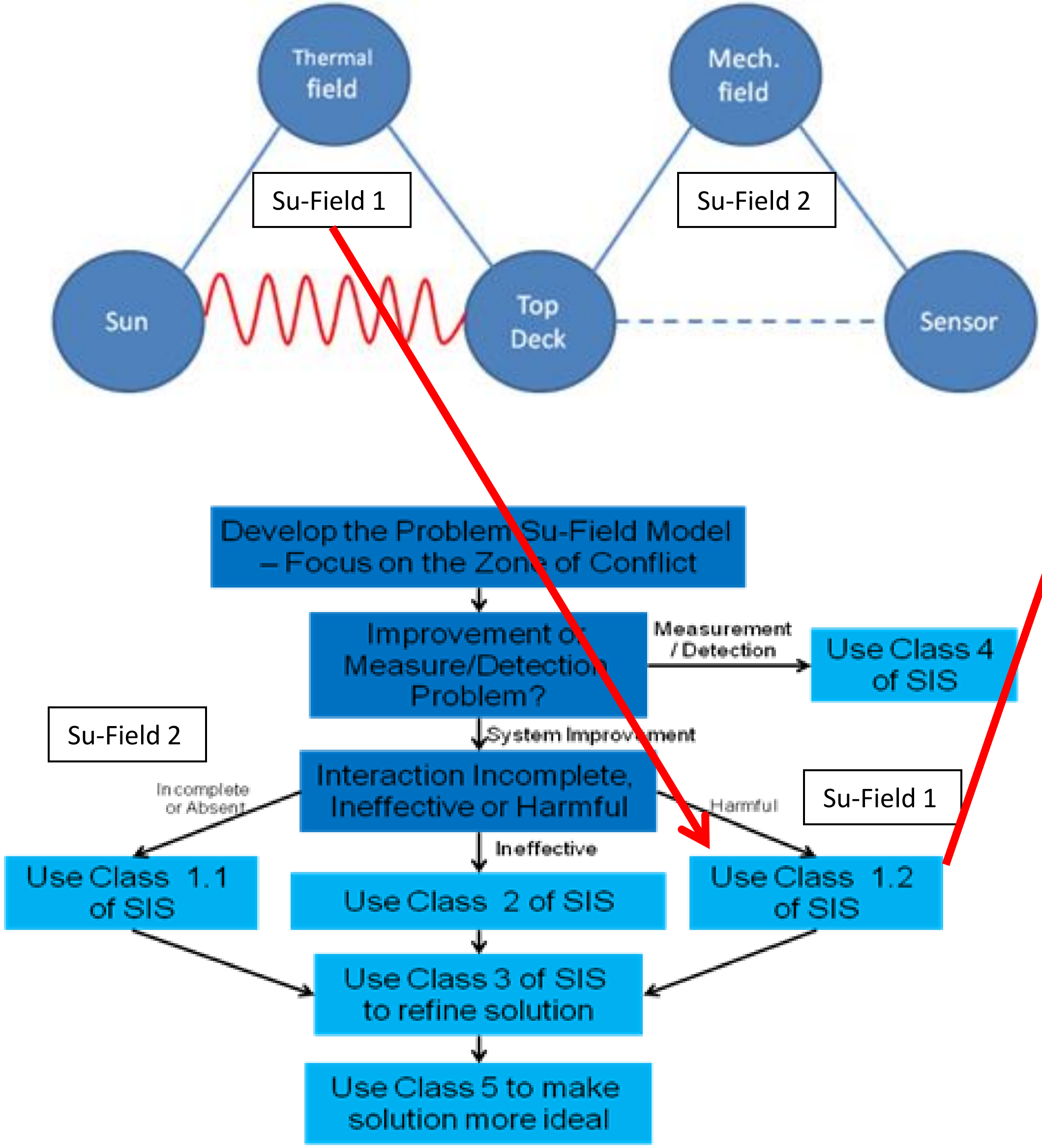
3.6. Apply Su-Field Analysis and Standard Solutions



For Example:
SIS 1.2.3. - The harmful action is caused by a field. Introduce an element S3 to absorb the harmful effects.

- "Skin" top deck with heat absorbing material the expands without effecting top deck itself and therefore without effecting sensor locations

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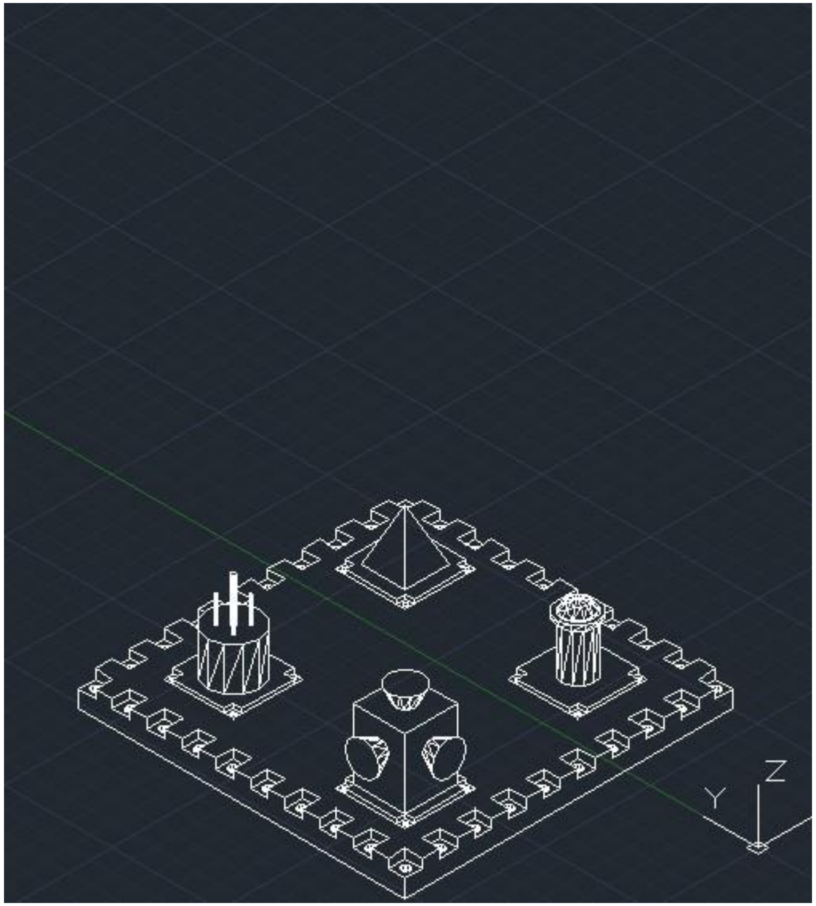
3.6. Apply Su-Field Analysis and Standard Solutions



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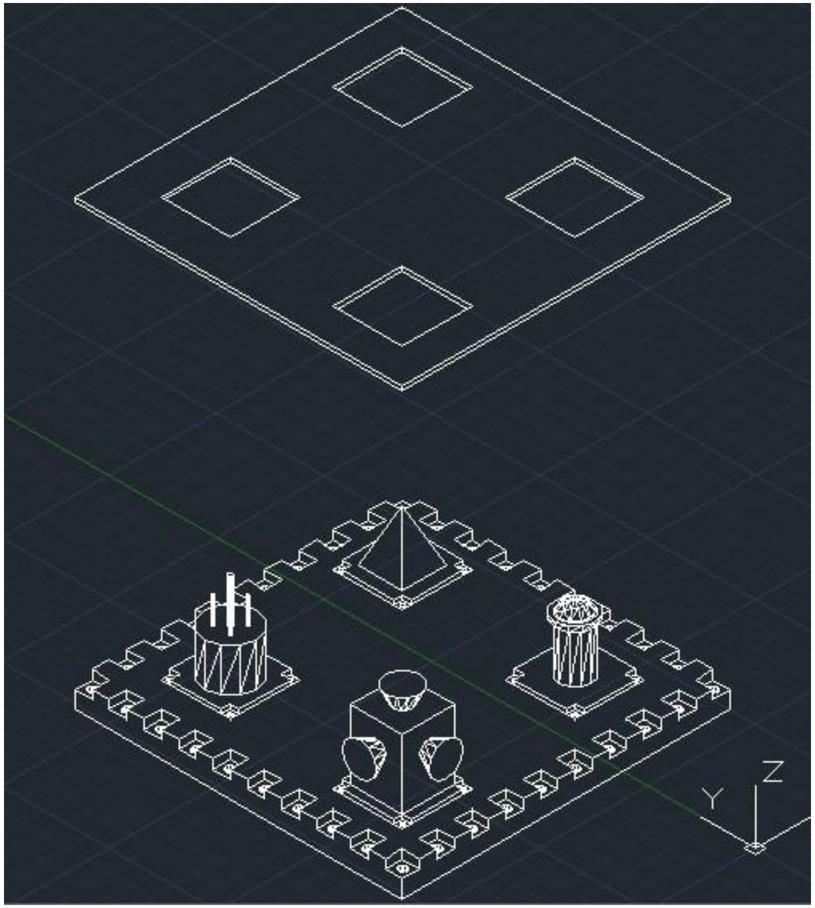

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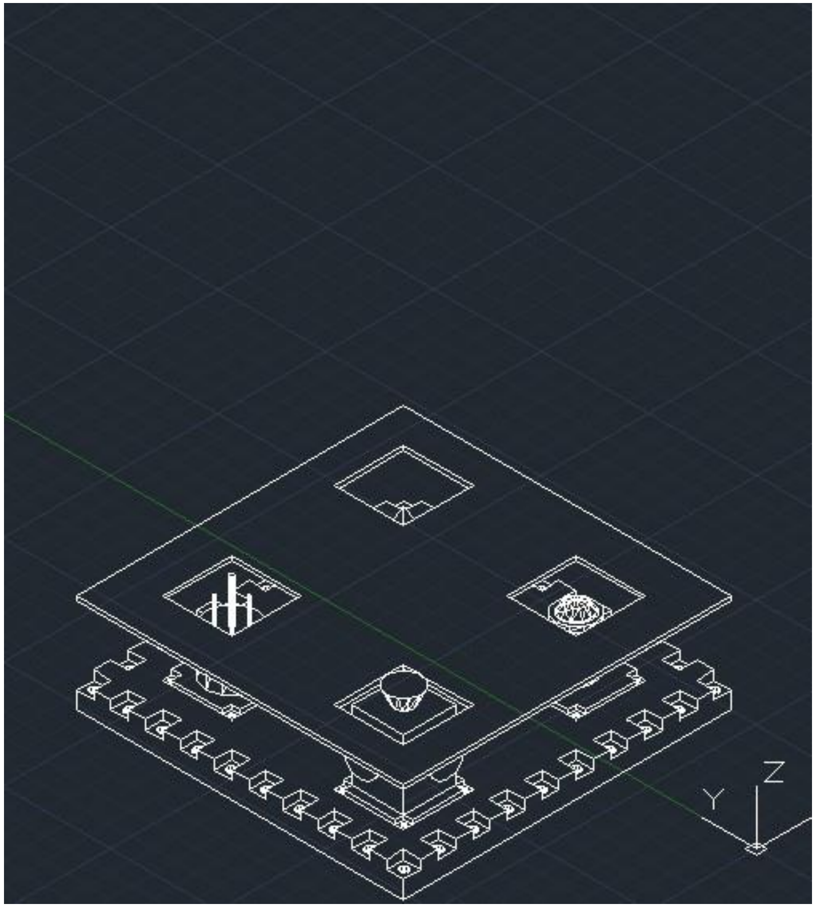

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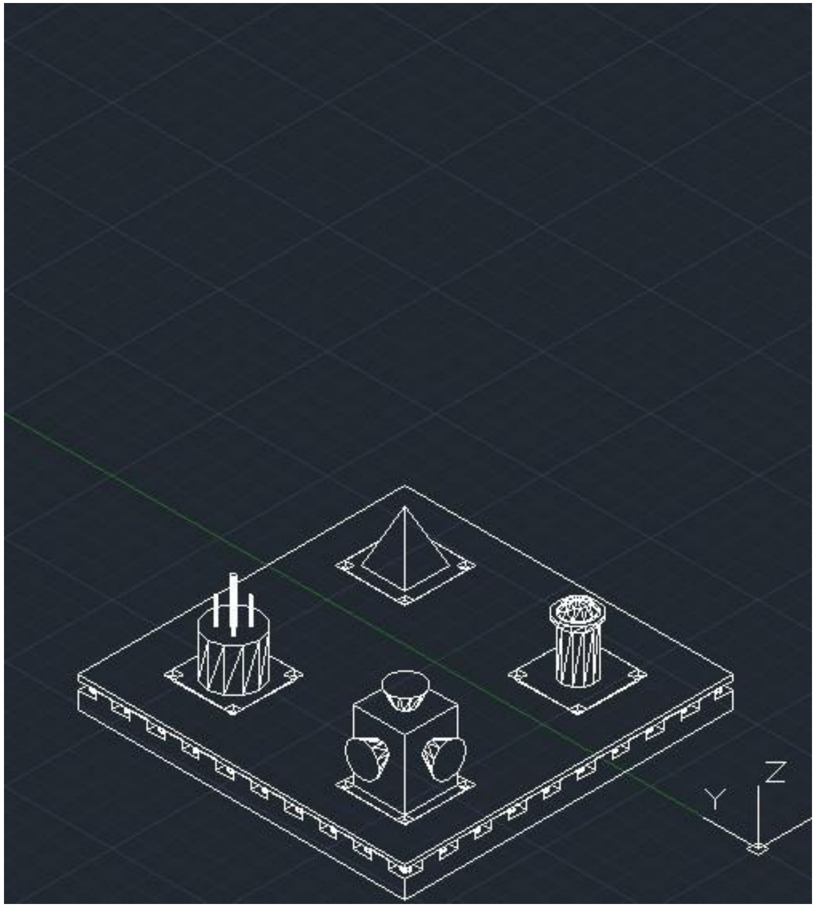

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Solution Summary and Results

- Air Force Goal was to produce an R&D Roadmap
- 45 Solutions concepts generated
- R&D roadmap developed for three separate categories:
  - Mechanical/Structural
  - Signal/Computing
  - System Integration

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