26th annual INCOSE international symposium

Edinburgh, UK
July 18 - 21, 2016

Implementation of a Systems Engineering Approach to the Management of a Planetary Defense Team Project in an Intensive Space Studies Program Using IPPD

Authors

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Presentation Outline

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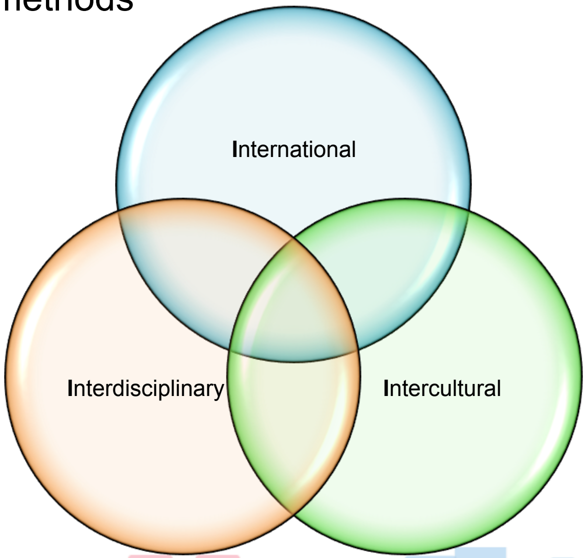
- Planetary Defense (PD) Team Project (PDTP)
  - READI Project
- Why PD is an important and challenging topic?
- Methodology
  - Phase I: Applied IPPD Method for PD Project
  - Phase II: Threat Specifications and Systems Engineering Plan
- Initial conditions for comet scenario
- Project Management
- Team Dynamic Challenges and Risks
- Results and Recommendations for PD
- Conclusions

Planetary Defense Team Project (PDTP)

- 34 participants from 17 countries gathered for 9 weeks to tackle the PD challenge at ISU-SSP in Ohio – USA
- PDTP focuses on comet/asteroid threats with short warning period, few years
  - Looked at all areas that can be improved not just deflection methods
  - Results and recommendations for PD through 3Is
- Products of PDTP:
  - Roadmap for EArth Defense Initiatives (READI) Project



Why PD is an important and challenging topic?

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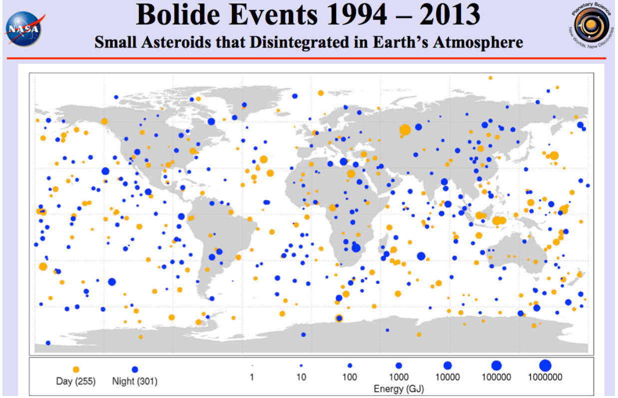


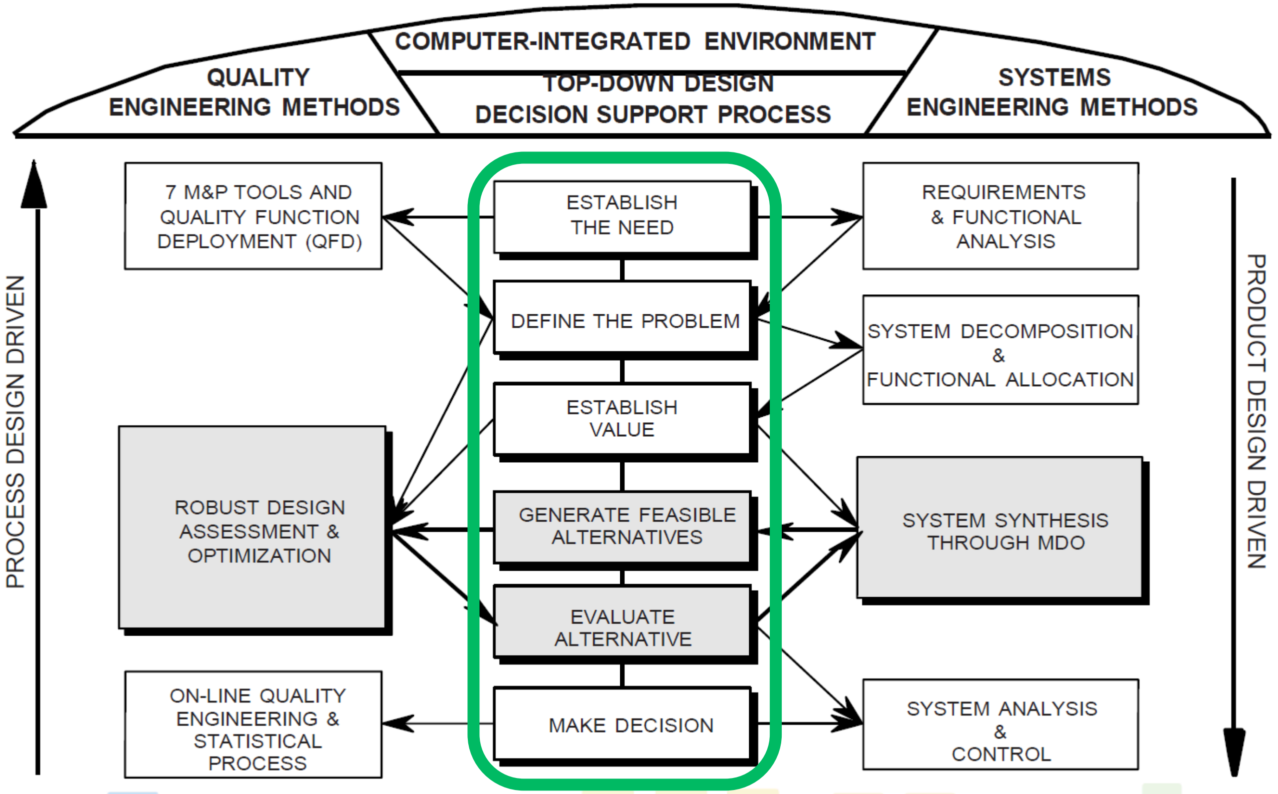
- Earth is constantly bombarded by various sizes of space objects
  - Major impact events have occurred in the Earth's past
  - Impacts from NEOs still occur today
- Past impact events:
  - 65 Million Years Ago (Dinosaur Extinction)
  - 1490 Ching-yang Meteorite Shower
  - 1908 Tunguska Event
  - 1994 Shoemaker-Levy Comet
  - 2013 Chelyabinsk Meteor
- General public is uneducated on the topic of cosmic hazards
- Solutions for comet threats with short warning periods are rarely discussed in the literature.
- Compared to asteroids, comets:
  - Are far less predictable
  - Have very high relative velocities
  - Release more energy upon impact
- PD is a complex problem:
  - Requires a bigger picture assessment of all the different aspects
  - We detect NEO with a relatively short time to act
  - 100,000s of asteroids/comets identified (Represent potential threats to life on Earth!)

The reality is that we are not prepared! We must act now!

Methodology

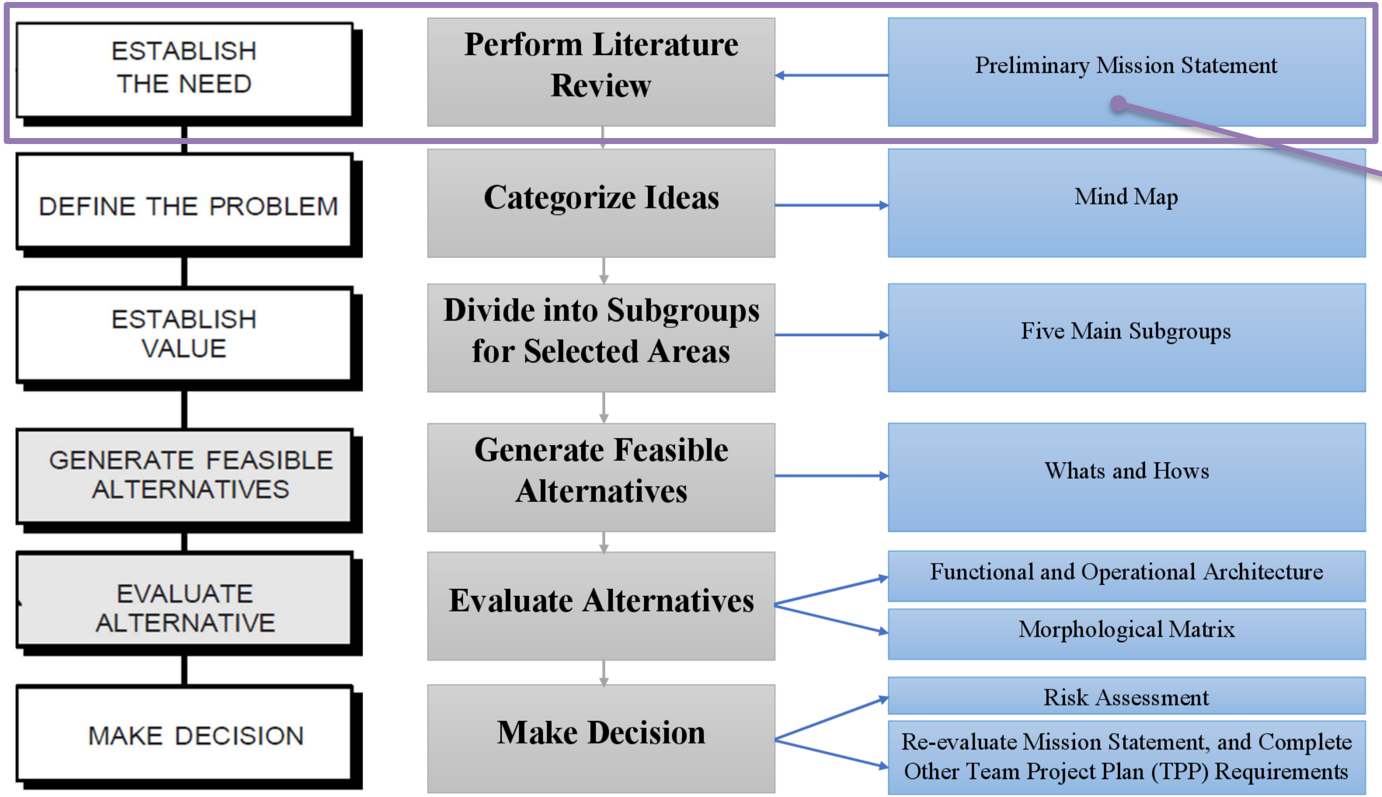
- Phase I: Used the Integrated Product and Process Development (IPPD) methodology to:
  - Mange the project execution
  - Identify mission statement
  - Define requirements and needs
  - Provide possible solutions
- Phase II: Dealt with the Systems Engineering (SE) plan for verifying and validating our work

Phase I: Applied IPPD Method for PD Project



- IPPD developed at Georgia Institute of Technology
- Why IPPD?
  - Couple systems and quality engineering methods
  - Provides structured decision making process

Phase I: Modelling IPPD for PD



{To develop a Planetary Defense Program for detection and mitigation of asteroid and comet threats with short warning periods, consisting of ground and space segments that include technologies, global cooperation, and public awareness}

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Phase I: Define the Problem

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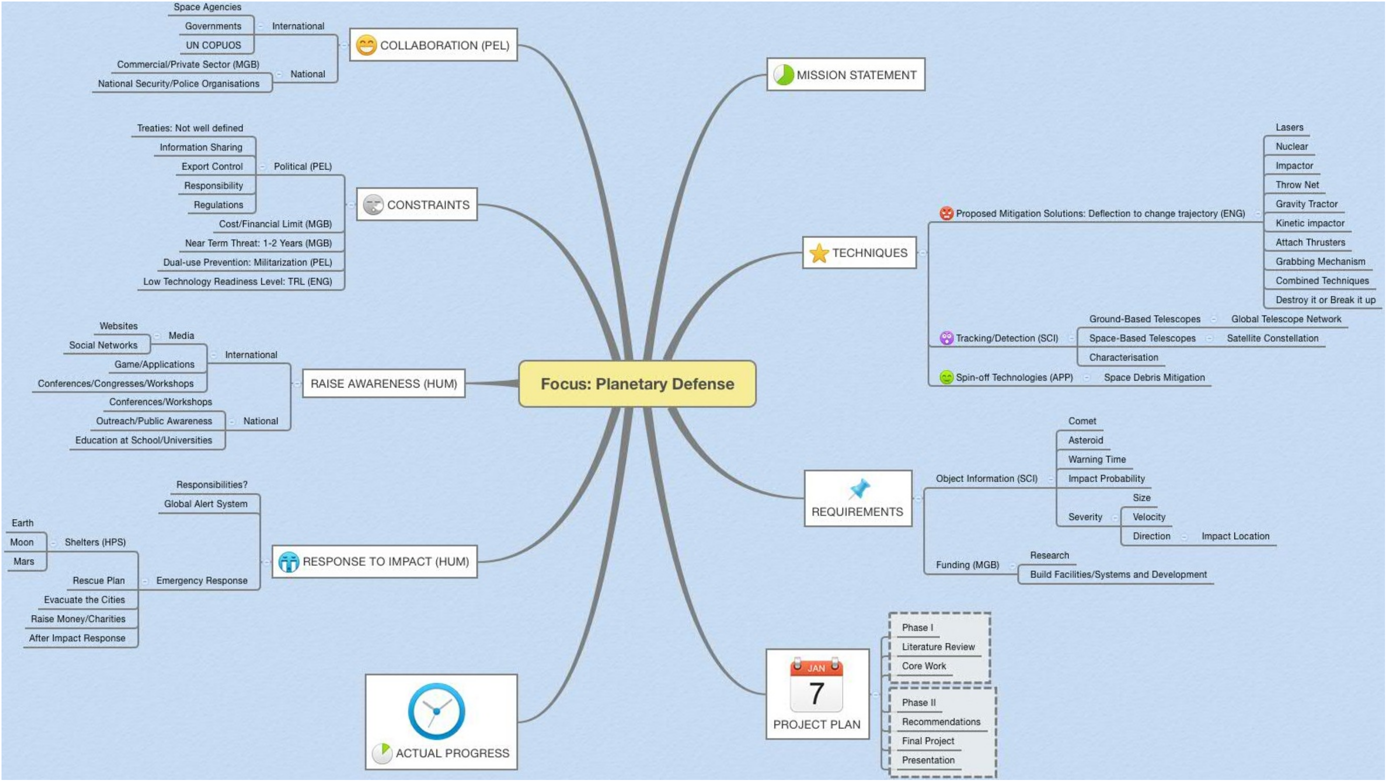

ISU Departments:
- SCI: Space Science
- ENG: Space Engineering
- HUM: Space Humanities
- APP: Space Applications
- HPS: Human Performance in Space
- PEL: Space Policy, Economics, and Law
- MGB: Space Management and Business

Phase I: Establish the Value

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- Main elements of PD project are:
  1. Detection and Tracking
  2. Deflection Techniques
  3. Global Collaboration
  4. Outreach and Education
  5. Evacuation and Recovery

	Weights Importance	Ground Coverage	Space Telescopes	In-Situ Characteristics	Orbiting Spacecraft Characteristics
Time to implement	2	4	3	1	2
Cost	2	2	3	5	4
Feasibility	3	5	5	3	4
Detection 90% <140m	3	1	3	N/A	N/A
Detection 90% 140m–1km	3	2	4	N/A	N/A
Detection 99% >1km	3	3	5	N/A	N/A
Trajectory	3	3	4	1	5
Composition	2	2	3	5	4
		58	81	34	47

Phase I: Generate Feasible Alternatives
And
Phase I: Evaluate Alternatives

*** N/A= Not Applicable**

Viable Options
N/A*
Not Feasible

	Increased Ground Coverage				**Space Telescopes**				**In-Situ Characterisation**	**Radar Characterisation**
	Optical	**IR**	**Radar**	**Lidar**	**Optical**	**IR**	**Radar**	**Lidar**		
Detection 90% < 140 m	Dedicated and Distributed network of professional observatories	N/A*	Sequare Kilometer Array (SKA, in construction)	N/A* (can't really be used for detetion)	N/A* (done from ground better)	>1m diameter dedicated telescope (double size of Sentinel), L2 point based telescope	Moon-based radar (bigger than Earth based)	N/A* (can't really be used for detection)	N/A*	Requires Close Passes
Detection 90% 140 m - 1 km	Reasign small telescopes to dedicated network (some what being done)		SKA (in construction)			Sentinel, NeoCam, NeoWise	N/A* (done from ground better)			
Detection 99% >1 km	Increase amateur astronomer coordination for better coverage		Build more Arecibo like radars (increse sky coverage)			CubeSat based telescope				
Trajectory	Distributed network for follow-up		Build more Arecibo like radars (increse sky coverage)	Dedicated network of lidar stations		CubeSat based telescope (constellation)		Space-based lidar observatories (better range than Earth-based, less dispersion of laser)	Spend probe to orbit asteroid	
Compasition	Spectroscopy	Spectroscopy	Ground penetrating radar	N/a*		Spectroscopy	Ground penetrating Moon-based radar	N/A*	Lander or penetrating radar	
Feasibility	Demonstrated	Impossible (atmosphere absorption)	Known techniques need to show application for detection	Requires powerful lasers, needs demonstration	Demostrated but not necessary	Demostrated	Theoretical	Theoretical	Demostrated	
Cost	Low	N/A	Very High	High	High	High	Impossibly high as of now	Very high (but could be brought down with NewSpace techniques)	Extremely high	

Phase I: Make a Decision

Likelihood of Risk	Time of Impact				
	Insignificant In 1 year	Minor In 2 years	Moderate In 5 years	Major In 10 years	Catastrophic In 20 years
Almost Certain : >90% chance	High	High	Extreme	Extreme	Extreme
Likely : between 50% and 90% chance	Moderate	High	High	Extreme	Extreme
Moderate : between 10% and 50% chance	Low	Moderate	High	Extreme	Extreme
Unlikely : between 3% and 10% chance	Low	Low	Moderate	High	Extreme
Rare : <3%	Low	Low	Moderate	High	High

- Used a variation of a Quality Function Deployment (QFD) to map customer voice to the engineering characteristics needed

Phase II: Threat Specifications and Systems Engineering Plan

Threat Initial Inputs (Detection)

Type:	Comet
Initial Size:	500 m
Impact Fragmentation:	400 m
Relative Velocity:	30 km/s (orbital)
Shape:	Peanut Sized (Knobbly)
Trajectory:	0.98 e, 50 AU semi-major axis
Composition:	Ice (water, methane, ammonia) Dust
Impact Probability:	Starts 1%, increases to 100% after 2 years, and impact

OPTIMISTIC: SUCCESS!

Deflection:
System works, high TRL and ORL achieved

Global Collaboration:
Security Council provides IMAG approval to act

Outreach:
People are educated and aware of threat and know how to deal with it

Evacuation:
Plan is ready and not implemented due to successful deflection

Location:
Location anticipated : Indian Ocean
Location attacked : No attack

PESSIMISTIC: FAILURE!

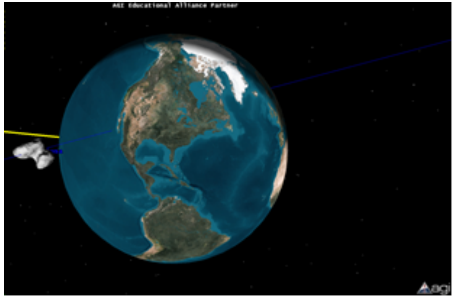
Deflection:
System works but it redirects it to another unanticipated location

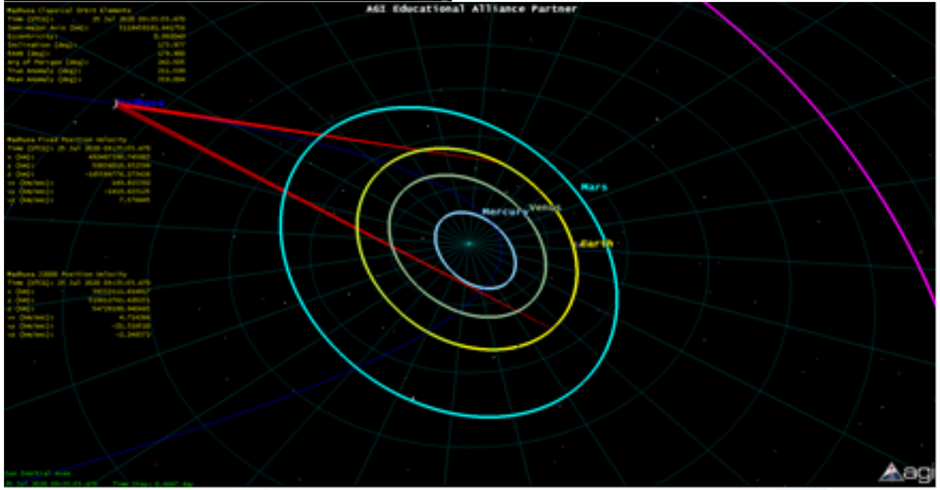
Global Collaboration:
Multi-lateral response under "Responsibility to Act"

Outreach:
People were aware of threat but ignore it, panic develops

Evacuation:
Plan is ready for a large city but there is not much time to evacuate people due to redirection

Location:
Location anticipated : Indian Ocean
Location attacked : Large city





Phase II: ISU's 7 Departments Requirements

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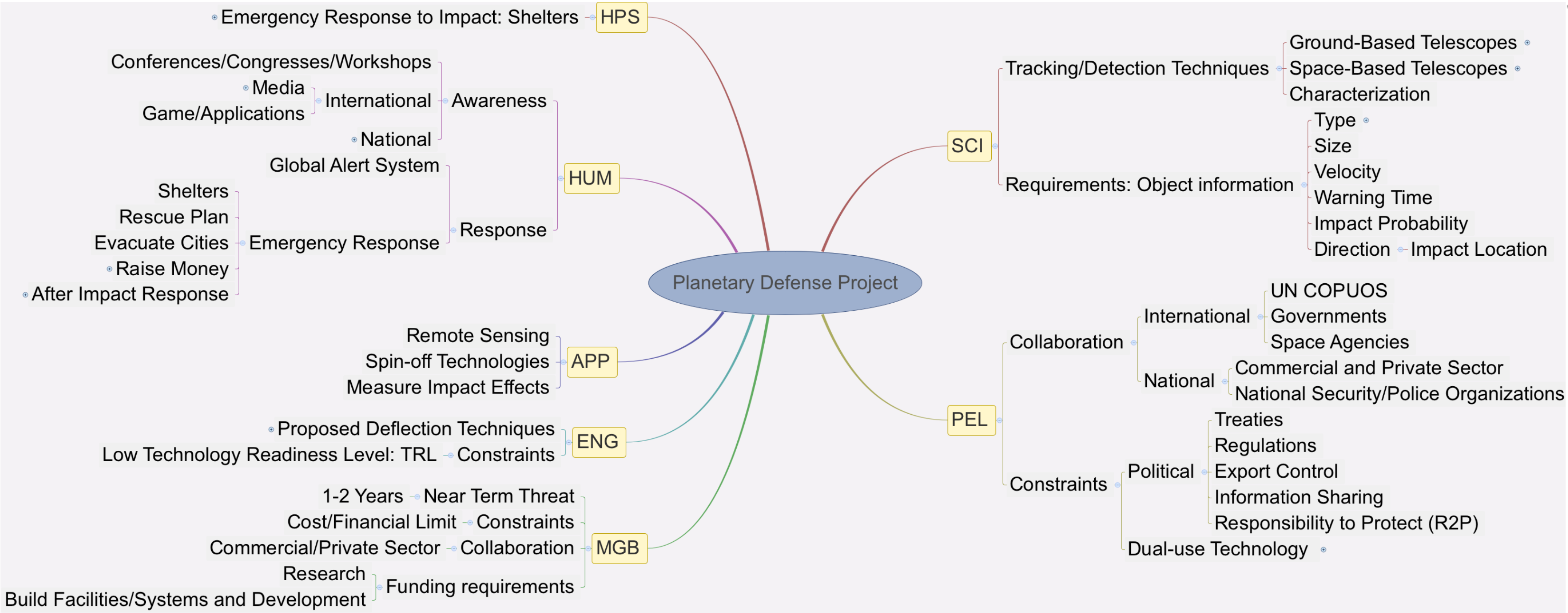
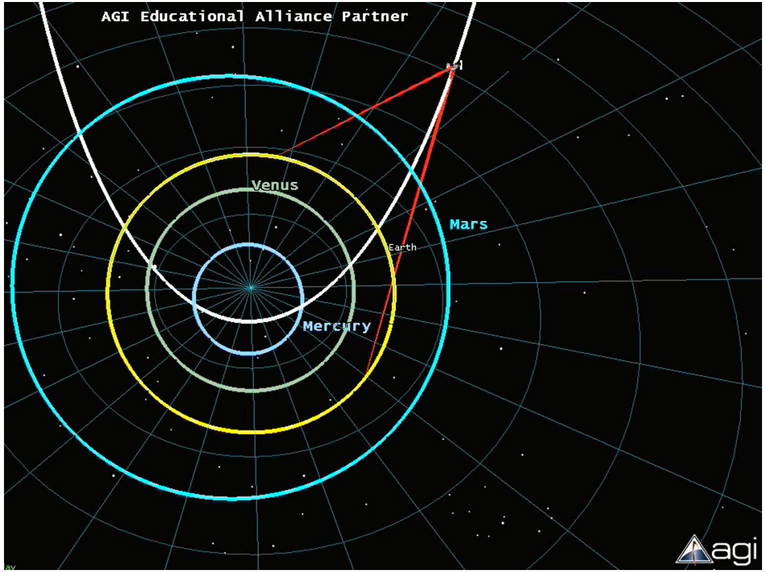


Project Management

- Work Breakdown Structure:
  - Gantt Chart
  - Ensure all tasks completed prior to the main milestone
  - Identify critical paths to completion
- Team Structure
  - Organizational charts
  - Matrix structure
  - 5 technical groups
  - 7 department liaisons
- Modelling and Simulation
  - STK
- Risks and Contingency Plans



Team Dynamic Challenges and Risks

- Diverse Backgrounds
  - 34 people coming from 17 countries
  - Different professional backgrounds
- Psychological Aspect
  - Away from family and friends for > 9 weeks
  - SSP environment similar to analogue missions
- Team Building and Team Dynamics
  - Social activities
  - Communications
- Human Factors

Results and Recommendations for PD

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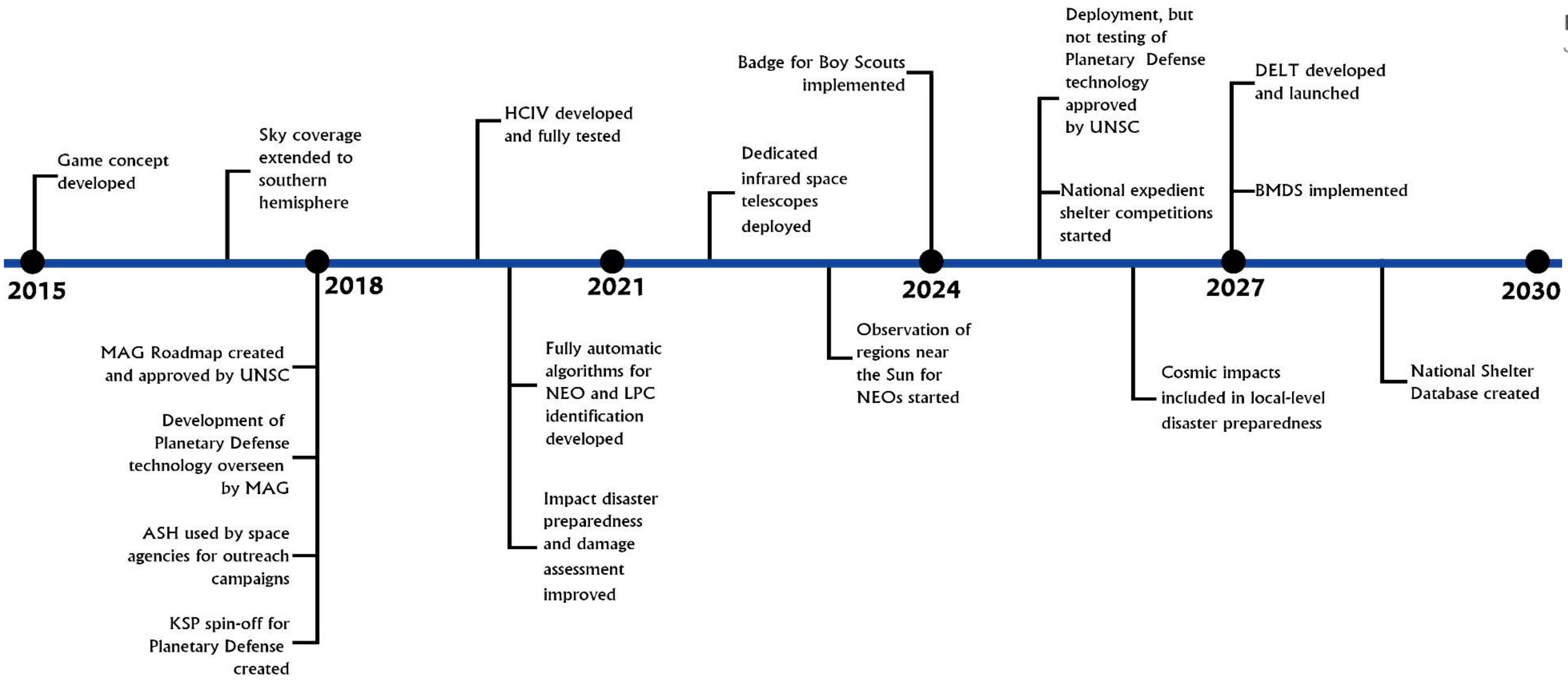

Conclusions

- Described the use of the IPPD method as a SE approach applied to a PD project
- Explained how IPPD method was used for different areas of our project
- Explained how SE programmatic processes helped to manage a challenging project and derive solutions
- Presented the modelling of the SE process with the aid of project management tools
- Discussed the methodology used to break down the PD complex problem into more sizable chunks
- IPPD method worked well in managing this complex project in a short period of time

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Acknowledgements

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Organizational Structure

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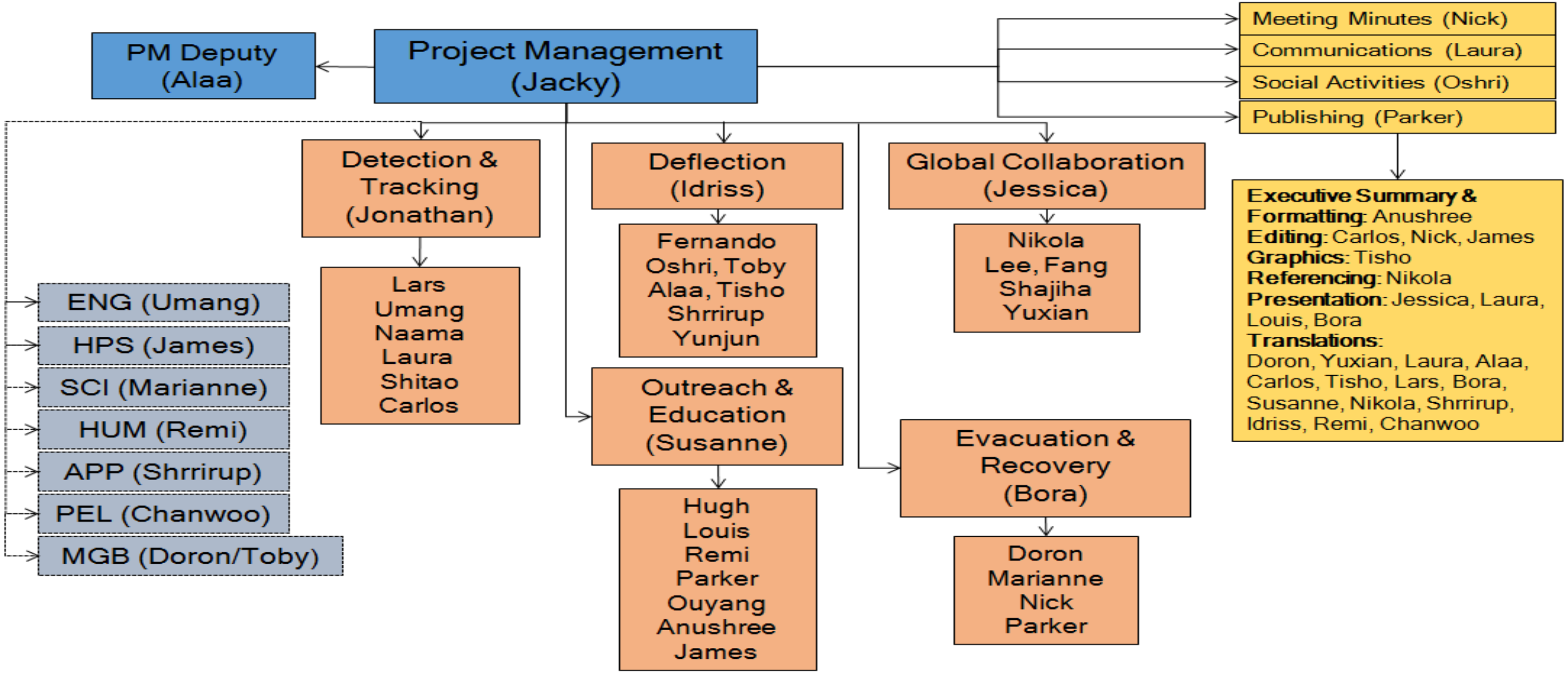

Risk Logs

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Topic: Planetary Defense Team Project (PDTP)			Description	Impact	Countermeasures
RISK IDENTIFIER: PDTP/RL01	Risk Category: Project Mngmt	Current Status: Reduced	Missing deadlines due to short-timeframe for deliverables	High effect on the project not being delivered on time	Put realistic plans and allow reasonable safety-margin
Probability: Medium	Author: Alaa	Date Identified: 06/20/2015			
Proximity: Daily	Owner: Project Leads	Date of Last Update: 07/10/2015			
RISK IDENTIFIER: PDTP/RL02	Risk Category: Organizational	Current Status: Resolved	Lack of communication among subgroup leads and programmatic point of contacts; disagreements between department liaisons and leads	Detriment on project execution	Ensure clear direction is given for tasks and lines of communication are understood
Probability: High	Author: Jacky	Date Identified: 06/20/2015			
Proximity: Daily	Owner: Project Leads	Date of Last Update: 07/10/2015			
RISK IDENTIFIER: PDTP/RL03	Risk Category: Technical	Current Status: Reducing	Frustration from people with experience in an area trying to explain people with less experience or not knowledgeable on a subject area	Subgroup members being de-motivated to work on the group deliverables	Talk in private with them and find common ground on learning experiences for both ends, the one for knowledge interchange two-way communication rather than knowledge transfer
Probability: Medium	Author: Jacky	Date Identified: 07/05/2015			
Proximity: Weekly	Owner: Project Leads	Date of Last Update: 07/12/2015			
RISK IDENTIFIER: PDTP/RL04	Risk Category: External	Current Status: Reducing	Not providing ideas and/or misunderstandings due to language barrier	Good ideas being overlooked and not getting active participation from all members	Two-way communication, remind non-native speakers to get their voices and opinions heard, and native speakers to provide an open environment where they can express their points of view
Probability: Medium	Author: Jacky	Date Identified: 06/21/2015			
Proximity: Daily	Owner: All	Date of Last Update: 06/29/2015			
RISK IDENTIFIER: PDTP/RL05	Risk Category: External	Current Status: Resolved	Not enough sleep and/or breaks	Low performance on project tasks and/or TP activities	Allow for constant breaks, energize team with some music, appoint a lead for social activities
Probability: Medium	Author: Jacky	Date Identified: 06/29/2015			
Proximity: Weekly	Owner: Oshri	Date of Last Update: 07/02/2015			

Parameters	Damage Assessment			Evacuation Plan Level/Scope			Evacuation Execution Strategy					Recovery
	PRE: Modeling Before Detection	PRE: Modeling with Detection Data	POST: Damage Assessment	Municipal	National	International	Hardened Shelters / Tents	Evacuation (Human)	Evacuation (Human - Domestic Animals)	Asteroid Spcific (NEW)	Use Pre-Existing plan (OLD)	Municipal / National / International
Cost	Low	Low	High	Meduim	Medium-high	High	High	Medium	Medium- high	High	Low	High
People power	Low	Low	Very high people on the ground plus remote sensing	Low	Medium	high	High	High	High	High	Low-medium	High
Time to implement	Low (ongoing)	Low (with pre-existing infrastructure)	Initial = week Final report = 1-2 years	Low	Medium	High (depends on the certainty)	High	Medium-low	Medium- high	High	Low-medium	High
Level of collaboration	Low	Low	High	Low	Low	High	High (if international)	High	High	High	Medium	High
Technology requirements	Low	Low	Meduim to high	Low	Medium	Medium	Medium for existing Relativaly high for new infrastructure (underground shelters)	Low	Medium	High	Low	High

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