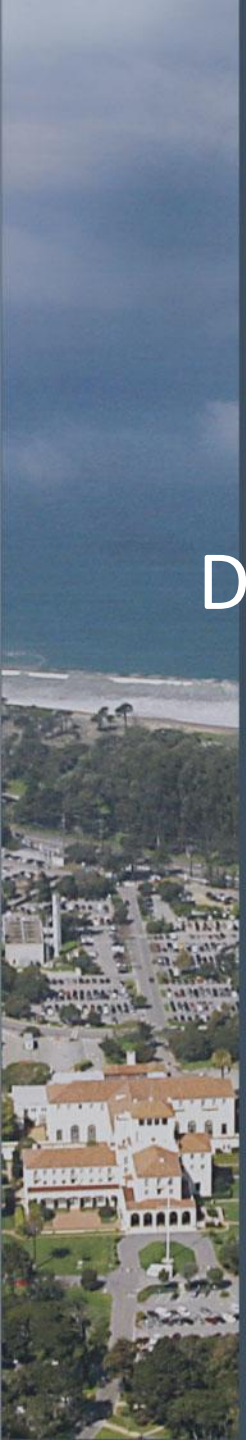

NAVAL
POSTGRADUATE
SCHOOL

Developing Defense Systems Engineering into Engineering Competency via Multi-Quarter Carry-Through Projects

NDIA Systems Engineering Conference
San Diego, CA

27 October 2011

The Nation's Premiere Defense Research University

Monterey, California
WWW.NPS.EDU

Project Sponsor – ASD(R&E) – SERC Team

SYSTEMS ENGINEERING
Research Center

Virginia Tech

Penn State Great Valley

AFIT
The Air Force Institute of Technology

Stevens Institute of Technology
The Innovation University

Auburn University

Missouri S&T
University of Science & Technology

SMU

United States Naval Academy
1845-1995

University of Maryland

Wayne State University

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NPS SE Masters Program Overview

Resident (580)

Individual Thesis

Domain/Track - Cohesive combination of 7 engineering, operations research, acquisition, or management topic courses

- Logistics Engineering (SE)
- Human Systems Engineering (SE)
- Systems Analysis (OR)
- Engineering Risk (SE)
- Test and Evaluation (SE)

ESR

Nine Common SE Core Courses for All SE Masters Degrees

- Systems Integration and Development
- Software Systems Engineering
- System Architecture and Design
- Capability Engineering
- Engineering Economics and Cost Estimation
- Fundamentals of Engineering Project Management
- Systems Assessment
- System Suitability
- Fundamentals of Systems Engineering

Resident Program Requires Minimum of 6 Quarters (Full Time)

Distributed Learning (311)

Individual Thesis/Team Based Capstone Project

Domain/Track - Cohesive combination of 4 engineering, operations research, acquisition, or management topic courses

580X P-Code ESR Not Required

DL Program Requires Minimum of 8 Quarters (Part Time)

Program Objectives

- Resident and non-resident programs share common nine course core curriculum
- Informed by INCOSE reference curricula and DOD SE Competencies
- Course objectives mapped to ESRs Navy sponsor (NAVSEA); consistent with SPRDE-SE/PSE Competencies
- Burnt orange courses compose the SE certificate
- Degree requirements met by core, 4 course track, and 3 course project

Fundamentals of Systems Engineering
System Suitability
Systems Assessment
Fundamentals of Engineering Project Management
Engineering Economics and Cost Estimation
Capability Engineering
System Architecture and Design
Software Systems Engineering
Systems Integration and Development

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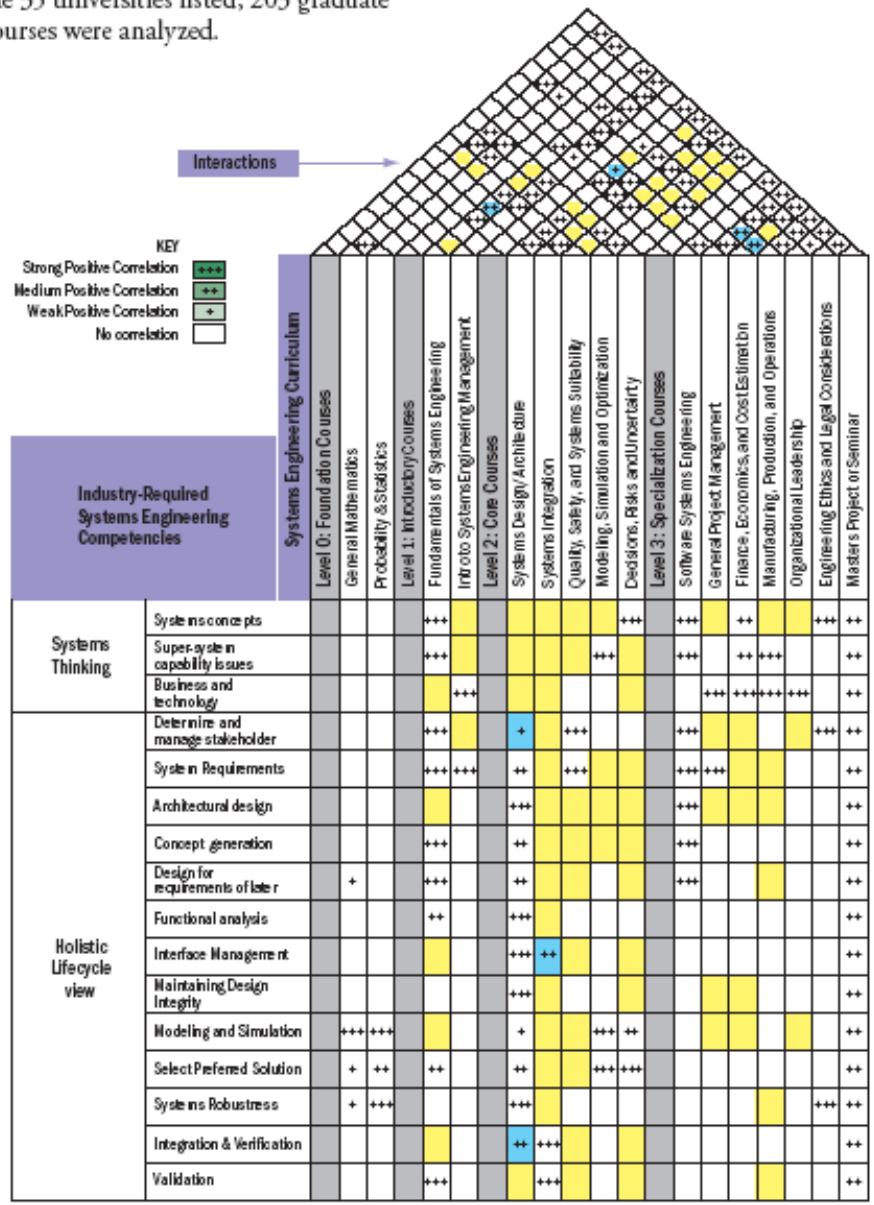
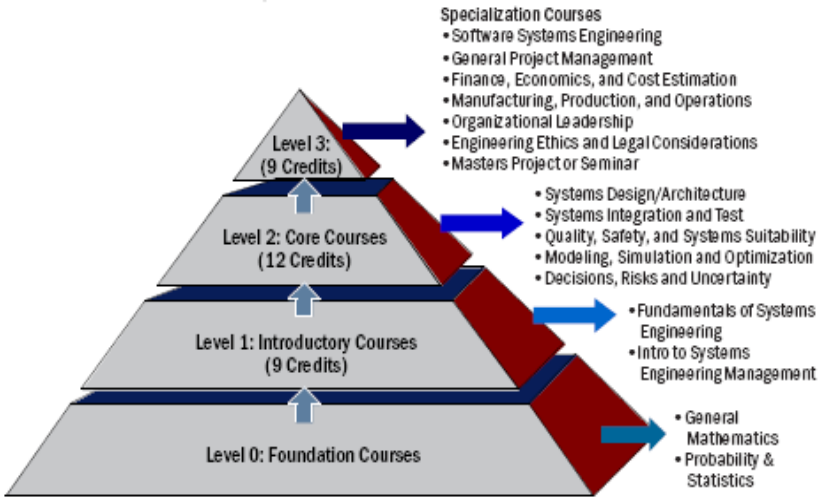
DoD Sponsored SE Reference Curriculum

the 35 universities listed, 203 graduate courses were analyzed.



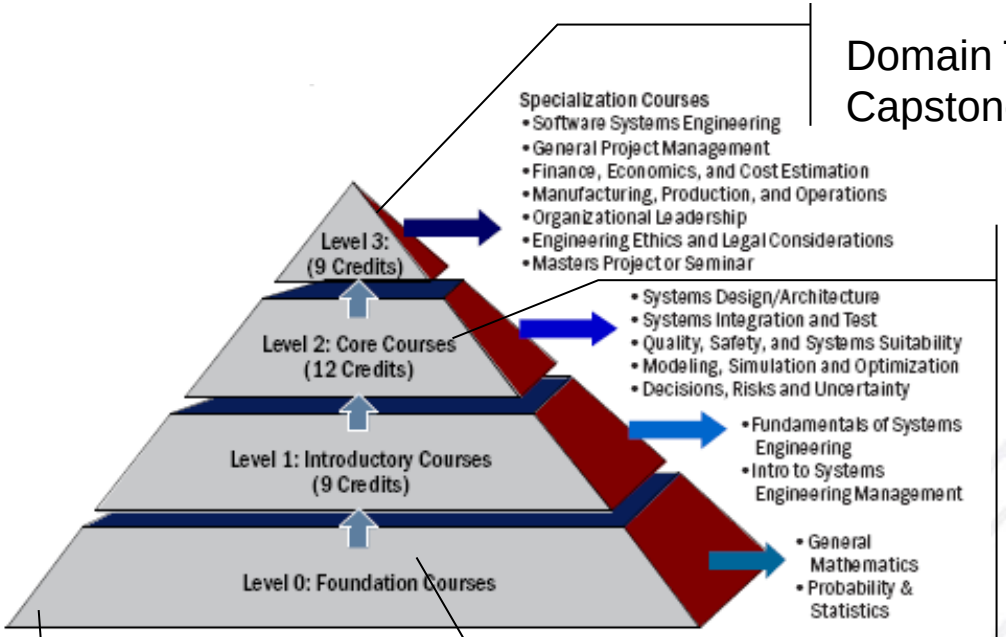


KEY

Strong Positive Correlation	+++
Medium Positive Correlation	++
Weak Positive Correlation	+
No Correlation	
Identified Gaps	
Identified Improvements	

Jain, Squires, Verma, Chandrasekaran – July 2007

NPS to Reference Curriculum Mapping



Domain Track Courses (3)
Capstone Integrating Project (3)

System Suitability
System Assessment
Engineering Economics and Cost Estimation
Capability Engineering
System Architecting and Design
Software Systems Engineering
System Integration and Development

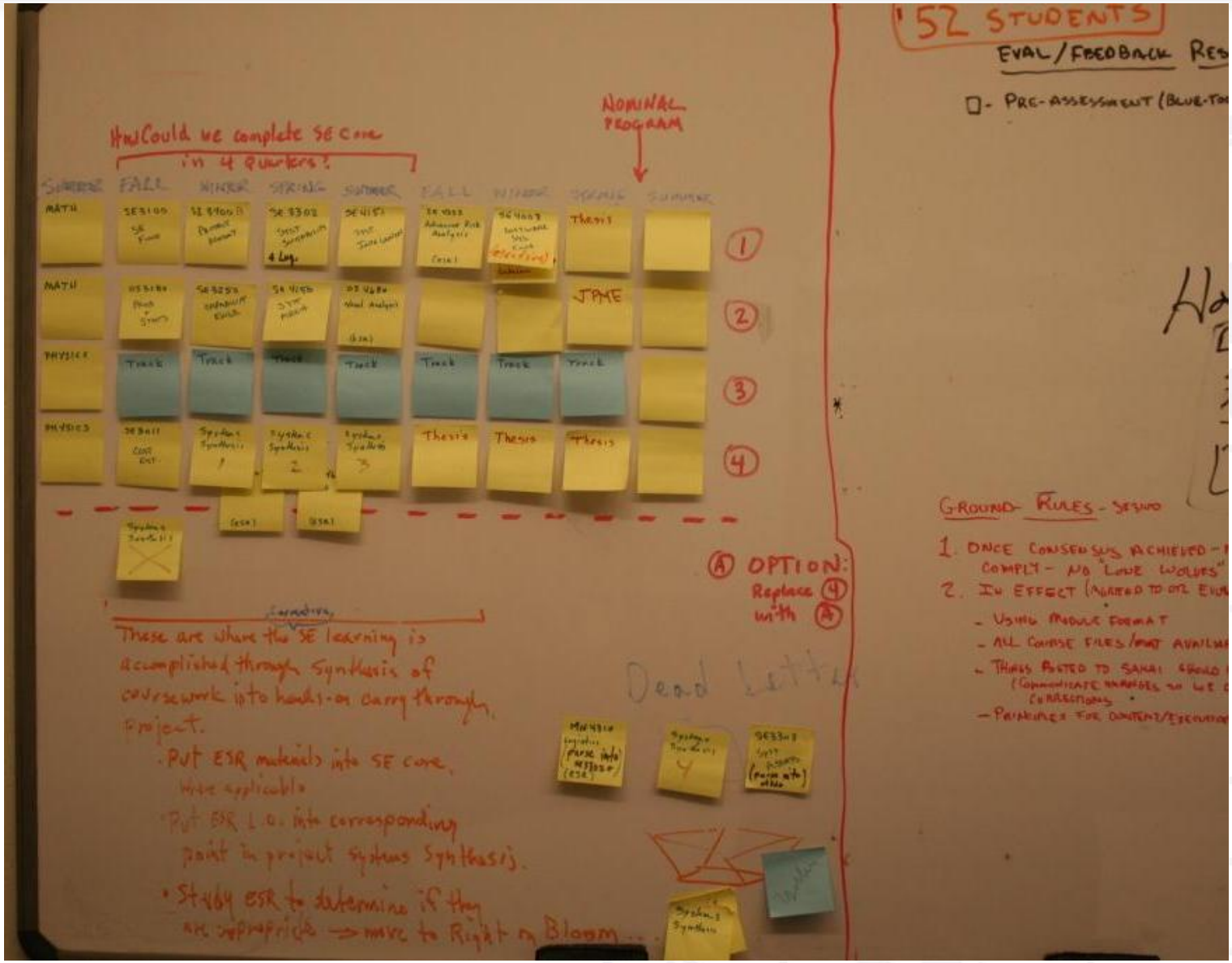
Fundamentals of Systems Engineering
Fundamentals of Engineering Project Management

Probability and Statistics for Systems Engineers

[Calculus Prerequisite]

NPS RT-19 War Room Objectives Affinity

NPS RT-19 War Room Sequencing Options



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Objectives Mapped to Competencies

Course and Objective	SE Competency
SE3100: Fundamentals of Systems Engineering	28: Strategic Thinking 25: System of Systems 27: Problem Solving 23: Acquisition, Element 34 15: Technical Planning
Elicit, elaborate and document system requirements based on user needs and operational objectives; translate them to technical requirements	4: Stakeholder Requirements Definition 5: Requirements Analysis 9: Requirement Reviews
Create a system value hierarchy reflective of stakeholder goals	5: Requirements Analysis 14: Decision Analysis 16: Technical Assessment
Complete system functional analysis in support of requirements engineering using modeling tools such as IDEF0, FFBD, and other languages	2: Modeling and Simulation
Develop, evaluate and document alternative system architectures, using DoDAF products where appropriate	6: Architecture Design, Elements 6 & 8
Plan for system validation, to ensure technical performance measures map to operational characteristics	9: Verification, Element 12 10: Validation
SE4150: System Architecting and Design	24: SE Leadership 25: System of systems 27: Problem solving
Create system architectures consistent with stakeholder needs, systems thinking, and systems engineering life cycle models using model-based systems engineering (MBSE) methods.	5: Requirements analysis 6: Architecting Design, Elements 6, 7, 8 18: Requirements management
Construct alternative system architectures for balanced system solutions. Demonstrate their feasibility through simulation (executable architectures).	2: Modeling & simulation 6: Architecting Design, Elements 6, 8
Demonstrate coupling between system elements and value criteria (stakeholder requirements, performance, quality, investment) through requirements traceability and management.	6: Architecting Design, Elements 6, 7, 8
Analyze and compare alternatives against system-level evaluation criteria. Explain trade-offs. Recommend "best" architectures	6: Architecting Design, Elements 7, 8, 9

Course Structure and Material

Fall Qtr	Winter Qtr	Spring Qtr	Summer Qtr
SE 3100: Fundamentals of SE	SI3400: Engineering Project Management	SE4150: System Architecting & Design	SE4151: System Integration & Development
	SE3250: Capability Engineering	SE3302: System Suitability	SE4003: SW Systems Engineering
	SE3011: Eng Econ & Cost Estimation		

Individual Project

Carry-Through Project

Student Assessment

Competency	Measures of Competency			
	Knowledge	**Skill**	**Ability**	**Behavior**
Stakeholder Requirements	Instructor introduces and student learns relation between stakeholders, their needs, problems, and requirements	Student practices stakeholder analysis in an instructor guided individual project	Student shows intuititiveness and will to determine needs and requirements for a self-identified solution	Student demonstrates initiative to extend their definition of "wall"; exchanges ideas with other students while keeping their work confidential; and is motivated to go beyond the assignment to dig deeper into an area of interest
Requirements Analysis	Instructor introduces and student learns how to conduct and monitor the analysis of stakeholder requirements to ensure functional and performance feasibility and effectiveness	Student explores and practices hierarchical decomposition for processes, functions, performance, and quality for an instructor guided group project	Student shows will to decompose attributes and character to revise hierarchies over several weeks time	Student demonstrates motivation to experiment with various taxonomies and definitions
Requirements Reviews	Instructor introduces *walkthrough of requirements with stakeholders* and student learns the essence of elicitation, questioning, and prioritizing requirements	Student practices interviewing customer (instructor), determines practicality of requirements within the usage environment(s) within a self-determined lifecycle	Student shows strength of will to deal with fickleness of instructor's requirements and changes in requirements	Student demonstrates initiative to fill in necessary requirements, present them to instructor during one-on-one reviews
Manage Design Requirements	Instructor introduces the methods of managing design requirements and student learns the processes and tools	Student explores use of methods and tools, practicing with their self-determined design requirements	Student demonstrates effectiveness in managing requirements by both a concerted attention to detail as well as an intuitiveness about the consequences of ignored, missed, or incorrect design requirements	Student shows initiative and forward thinking about design requirements through inquisitiveness and motivated follow-up

RT-19 2011 Number of Students

		Degree Program			
		MSSE (580)	MSSEA (308)	Other	Total
Student Source	US Navy	20	18	2	**40**
	US Army		1	3	**4**
	DoD Civilians			2	**2**
	Int'l Civilians	2			**2**
	Total	**22**	**19**	**7**	**48**

Key Objectives

- The pilot project involves the following competencies, along with the entire SE Competency list provided by OSD(AT&L):
  a. Technical Basis for Cost
  b. Stakeholder Requirements Definition
  c. Requirements Analysis
  d. Architecture Design (some elements)
  e. Alternative Generation, Scoring, and Selection
  f. Modeling & Simulation; Safety Assurance (where applicable & feasible)
- Learning objectives for current curriculum derived from:
  a. Navy sponsor-provided Educational Skill Requirements (ESR)
  b. INCOSE SE Handbook
  c. CSEP related learning objectives
- The project revisits these learning objectives, expanding the context to include:
  a. Systems engineering competencies identified by OSD(AT&L)
     a. SPRDE SE/PSE
  b. ABET EAC harmonized (a) - (k) criteria
  c. CDIO reference curriculum

Student Project Context

- Project Carries Through Curriculum
- Implemented Through 'Hands-on' Lab Sections
  - Primarily SI3400, SE3302, SE4150, SE4151
  - Other courses relate to project (SE3100, SE3011)
  - Instructors for all courses involved as project advisors for full curriculum scope
- Learn by Doing
  - Apply theories & concepts from courses
- Formative and Summative Assessments
  - Direct (exams, assignments, observation, …)
  - Indirect (surveys)
  - Based on competency development

Don't just act like a systems engineer, be a systems engineer!

Student Products

- Fall 2010
  - Problem Definition
  - Preliminary Organization
  - Stakeholder Analysis
  - Initial CONOPS
- Spring 2011
  - System Architecture
  - Concept Design
  - System Modeling
    - Vitech CORE
- Winter 2011
  - SEMP
  - Requirements Elicitation
  - Requirements Definition
  - Function Flow
- Summer 2011
  - System Integration
  - Prototype Development
  - Project Demo

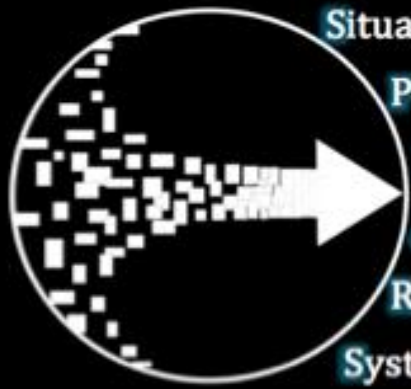
What DoD Problem Addressed

"An expeditionary assistance kit around low-cost, efficient, and sustainable prototypes such as solar cookers, small and transportable shelters, deployable information and communication technologies, water purifiers, and renewable energies. These materials would be packaged in mission-specific HA/DR kits for partner nation use ."

- Majority of Humanitarian Assistance/Disaster Relief casualties (HA/DR) occur in first three days
- US military capabilities:
  - Worldwide initial deployment: 22 hours
  - Worldwide large scale aid: seven days
    - Includes response management infrastructure
- Long term aid not a factor
  - After seven days, aid is available
- 1-3 day period - **capability gap**

DATA TO DECISIONS AS IT HAPPENS

S.P.E.A.R.S.



Situational Awareness
Providing
Enhanced
Analysis &
Response
System

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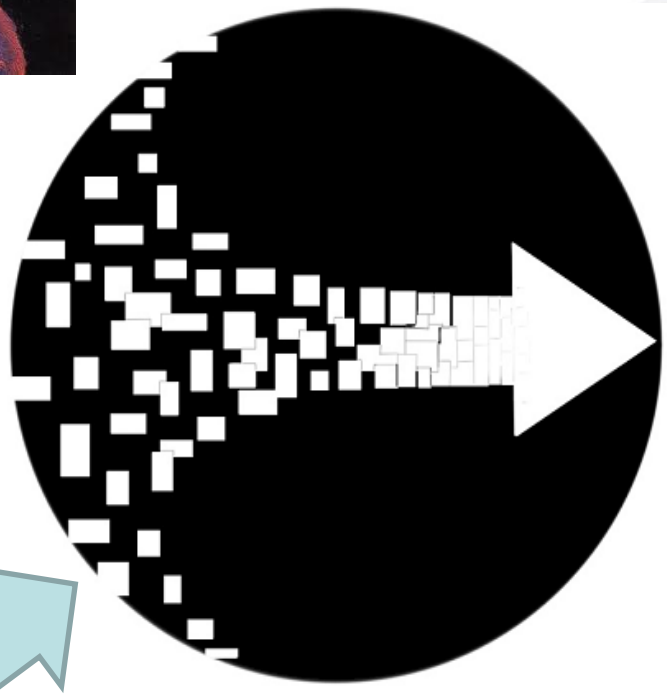
SPEARS Concept of Operations



CNN

USGS science for a changing world

twitter

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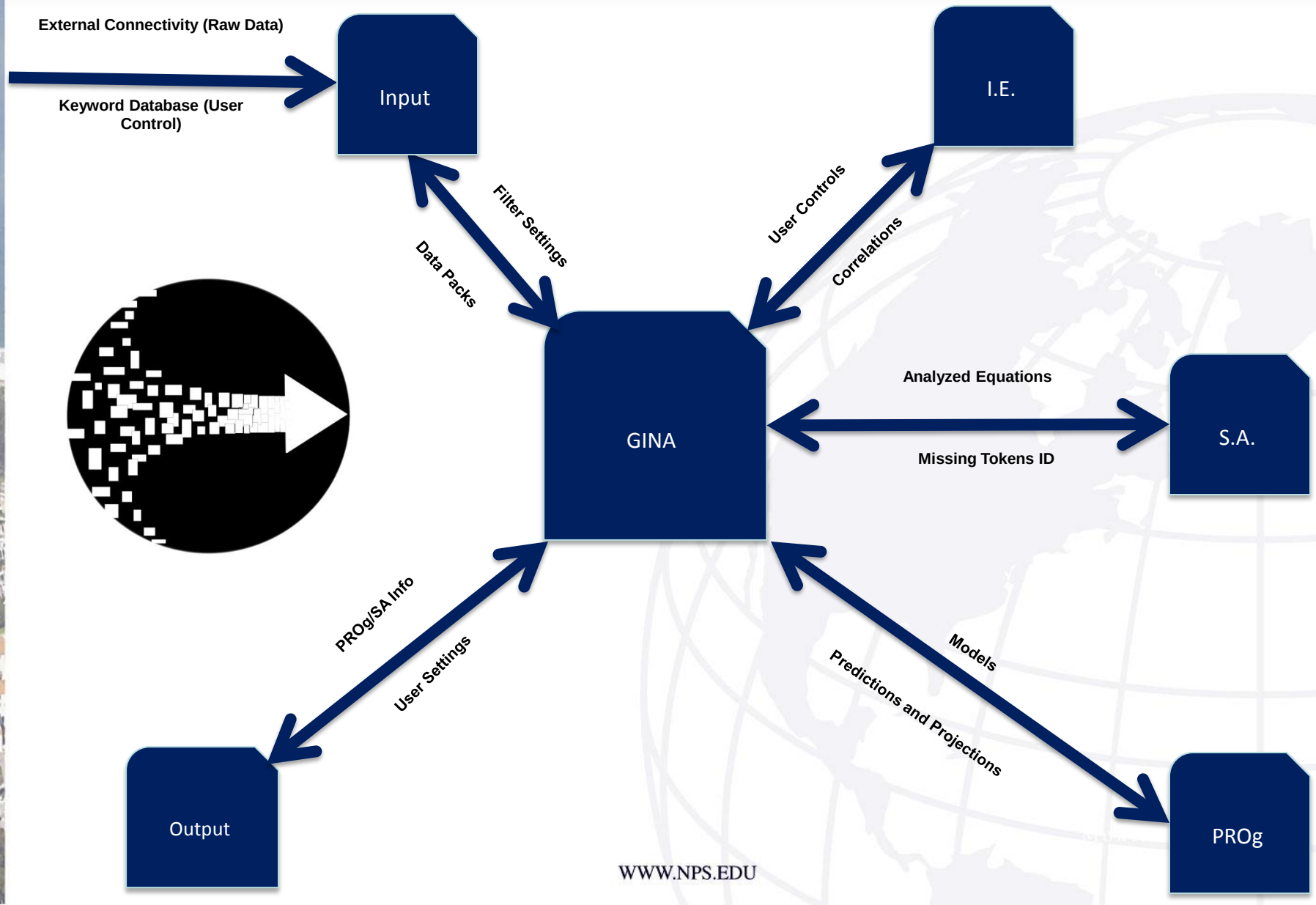
SPEARS Architecture



SPEARS Prototype Scenario

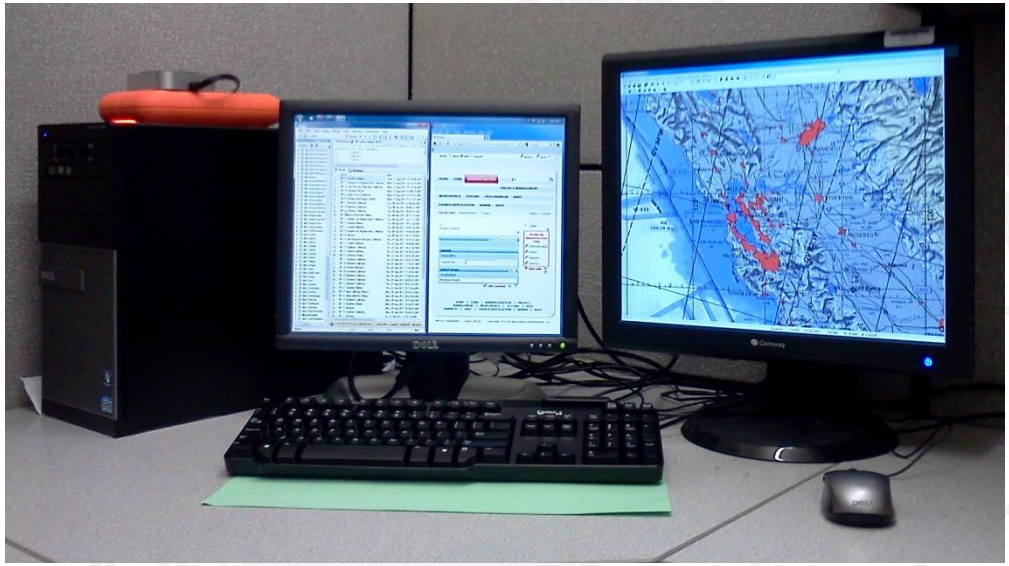
- Twitter trends
  - Shaking
  - Earthquake
  - Broken windows
- News sources
  - Power outages
  - Fires
- *USGS RSS Feed*

CNN®

USGS
science for a changing world

SPEARS Prototype

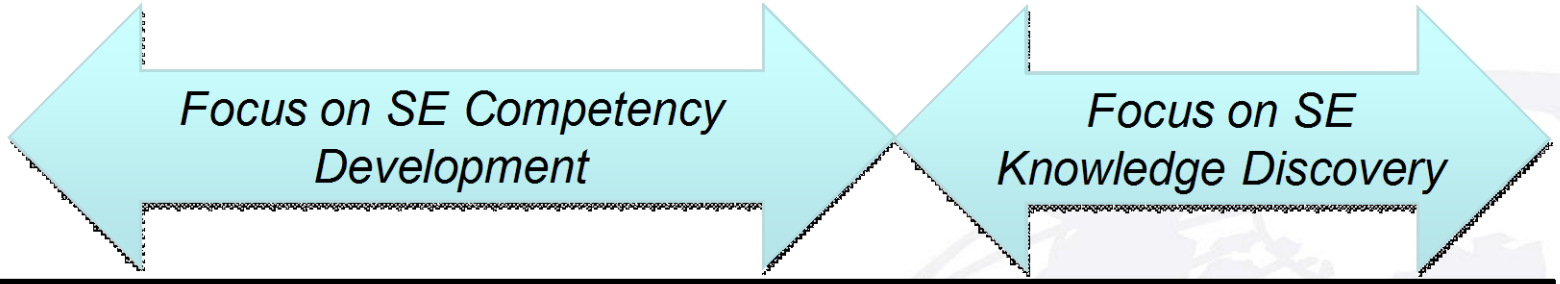
- Early development
- Physical hardware
  - Desktop computer
  - 2 x video monitors
  - 2 TB hard drive
- Software
  - Windows 7 Pro
  - GINA
  - FalconView 4.2.1
  - Cursor On Target / Excel2FV



RT-19 Outcomes

- Student Related
  - SPEARS offers way forward to close current capability gap
  - 1-3 day HA/DR response
  - Architecture viable for other Data to Decisions applications
  - Academic impact on 48 students
    - Exponential propagation throughout the Fleet
- Faculty Related
  - Developed learner-centered pedagogical approach
  - Assessment focusing on SE competency

Future Curriculum Pilot

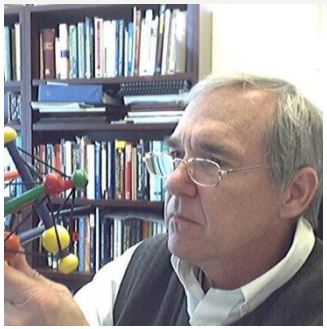


Math	SE3100	SI3400	SE3302	SE3303	Thesis	Thesis	Thesis
Math	OS3180	SE3011	SE4150	SE4151	Track	Military JPME	Thesis
Physics	Pre-req	SE3250	Track	SE4003	Adv SE	Adv SE	Track
Physics	Track	Conceive Lab	Design Lab	Implement & Operate Lab	Track	Track	Track

CDIO Inspired Project-Based Learning Labs

RT-19 Faculty

Cliff Whitcomb
Professor & Chair SE
831-656-2900
cawhitco@nps.edu



Gary Langford
Senior Lecturer
golangfo@nps.edu

Ali Rodgers
Director, Faculty Development
arodgers@nps.edu

Mark Stevens
Senior Lecturer
mstevens@nps.edu

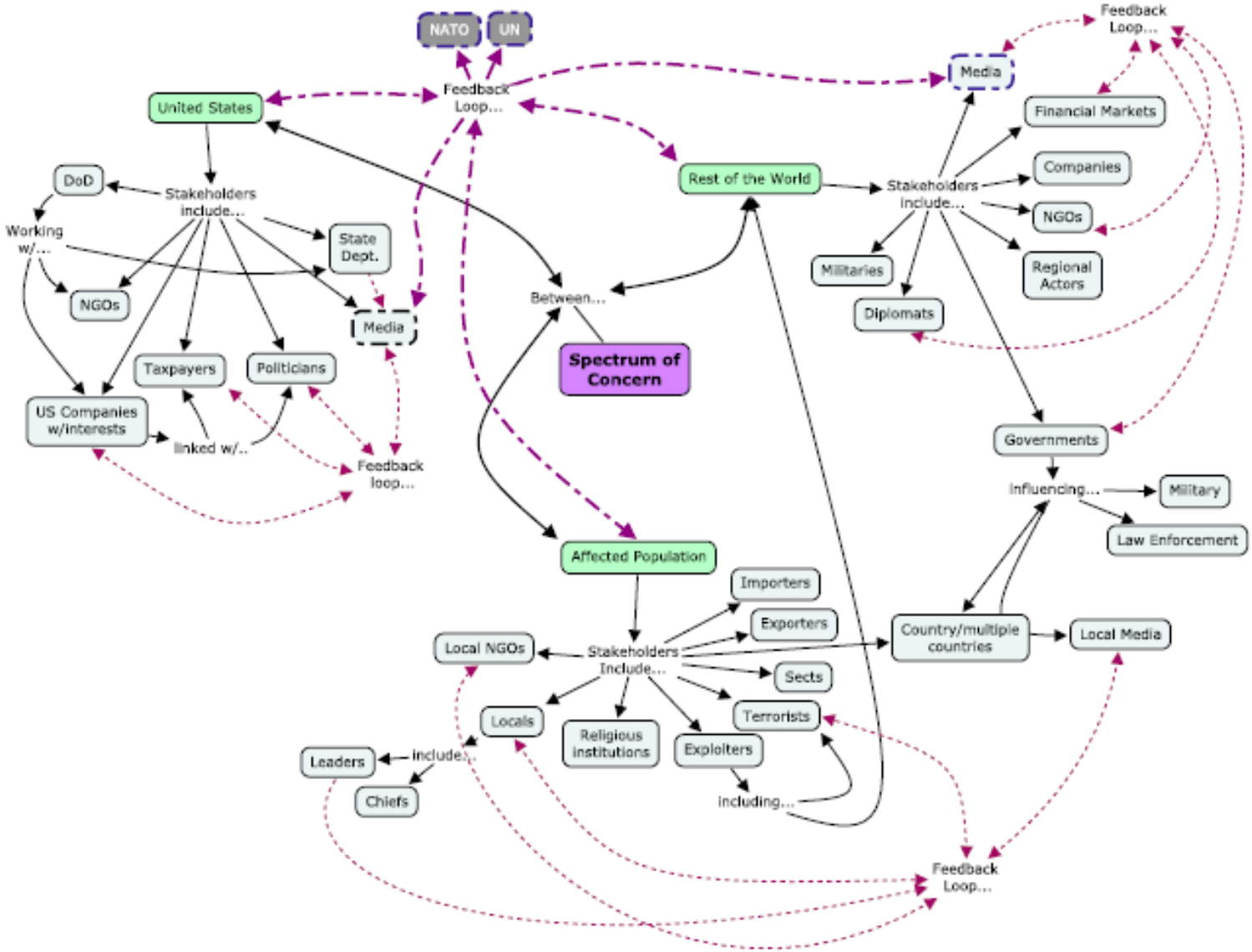
Gregory Miller
Senior Lecturer
gamiller@nps.edu

Diana Angelis
Associate Professor
diangeli@nps.edu

Outcome - SE Competencies NOT on List

- Providing a technical basis for comprehensive schedule realism (beyond #1, element 1)
- Modeling or simulation in support of operational realism, referenced to gap analysis (beyond #2, element 1)
- Systems thinking when analyzing stakeholder requirements (beyond #5, element 5; and beyond #6, element 6)
- Human interactions anticipated due to the delivered system engineered product (beyond #6, element 6)
- Trade analyses that include cost and schedule constraints (beyond #6, element 6)
- Consideration of boundary conditions beyond physical domains to include functional and process contexts (beyond #6, element 7)
- Additional consideration to reflect the consequences on architecture and its trade spaces for refinements made after requirements and specifications have been promulgated (beyond #8, element 11)
- Extending the view of validation to encompass determining the operational limitations of the requirements, functional and physical architectures, and the "as-built" implementation (beyond #10, element 14)
- Considerations of RAM using discrete Markov processes (developed as event-based structures), rather than simple formulations that average various contributions to RAM (beyond #13, element 17 and element 18)
- Discussion and understanding of the systems engineering management plan (SEMP) (beyond #15, element 20)
- Clear delineation between measures, metrics, and figures of merit in cardinal and ordinal scaling (beyond #16, element 21)
- Incorporating architectural perspective (i.e., resources, constraints, limitations, spatial and temporal interactions, and data context(s) (including scalability model(s) when considering, and "ensuring" interface definitions and compliances (beyond #21, element 27 and element 28).

Stakeholder Analysis



Requirements Elicitation

- Direct Elicitation
  - Student team
  - PACOM
  - AFRICOM
- VTC
- Follow-on Interactions
- Iteration

Notes from 2/11/2011 VTC with PACOM

PACOM attendees: Jim Ellert, NPS PAC
Dave Brown, J2
Biff Baker, Socio-cultural engagement officer

Problems facing PACOM

Issues and challenges in regards to HA/DR and Knowledge Management:
As an Intel/Plans Officer his interests are ISR/Enterprise architectures, UNCLAS architecture enhancements, and socio-cultural dynamics/human terrain. He spoke about 4 particular problem areas that RT-19 could explore:

a. SMARTphone technology. Using COTS technology to deploy downrange and use operationally for area assessments and HA/DR functions.
   i. The phones would be used to push/pull data and information.
   ii. A recent thesis topic at NPS was FIST (Field Information Support Tool), an Android-based SMARTphone that uses all functionality of the phone (GPS, DTG, etc.)
   iii. The interest would be to aggregate and fuse data that all could use, including international organizations
   iv. This should be a portal to push information from the field to COCOM users.
   v. Requires policies, procedures, and technical solutions.
b. Development of an UNCLAS geo-/non-geospatial data repository.
   i. The server and data must be structured for use by many different entities.
   ii. There are already several PORs (programs of record) that store and sort data in many different formats. There should be a method to pull information from these sources as well.
   iii. The database should be structured, yet flexible.
c. Business rules for what data is:
   i. Stored
   ii. Migrated
   iii. Replicated
   iv. Structured
d. Making improvements to the operating environment
   i. Envision a GUI with tools available:
      1. Geo-spatial analysis/RGS
      2. Google Earth
      3. Interface between 1&2
      4. Modeling/simulation
      5. Making the tools accessible via the internet

2. They envision each country with its own network, with a larger global network that sits on top. Each country should have its own local architecture and there should be a method to push local data to the global system.
3. Each person on the ground is a sensor – how do we take advantage of it?
4. We also want information from 'folks on the street.' How do we get that?
5. Supply chain tracking

SEMP

Research Topic 19 Systems Engineering Management Plan

Version 1.0 draft 1

Prepared by RT-19 Project Team

NPS Systems Engineering Students

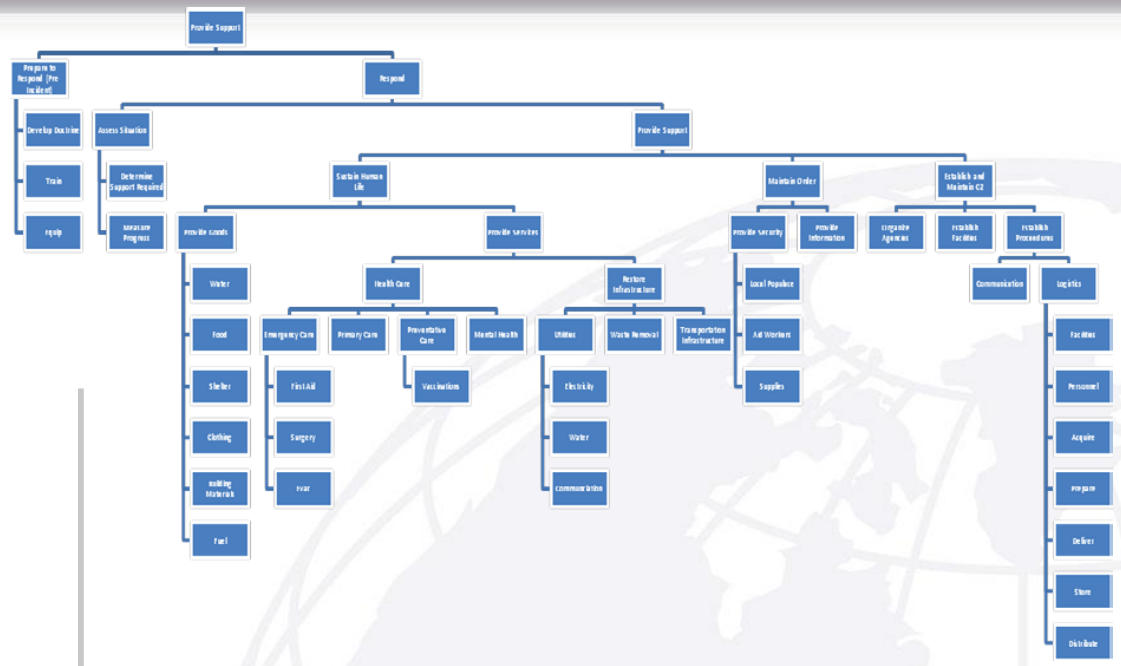
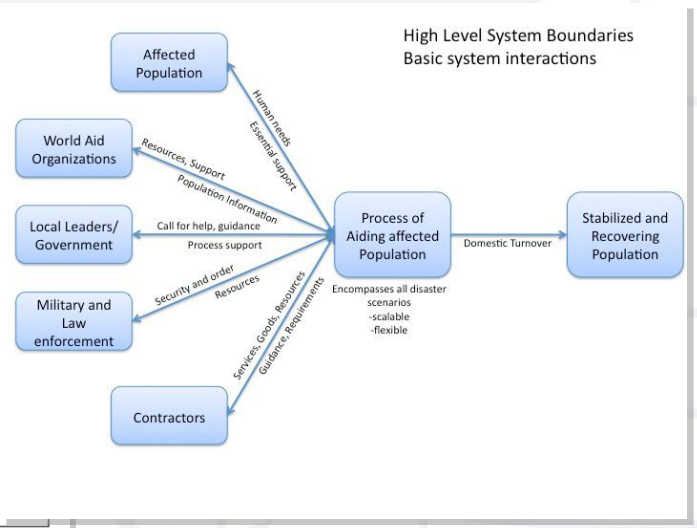


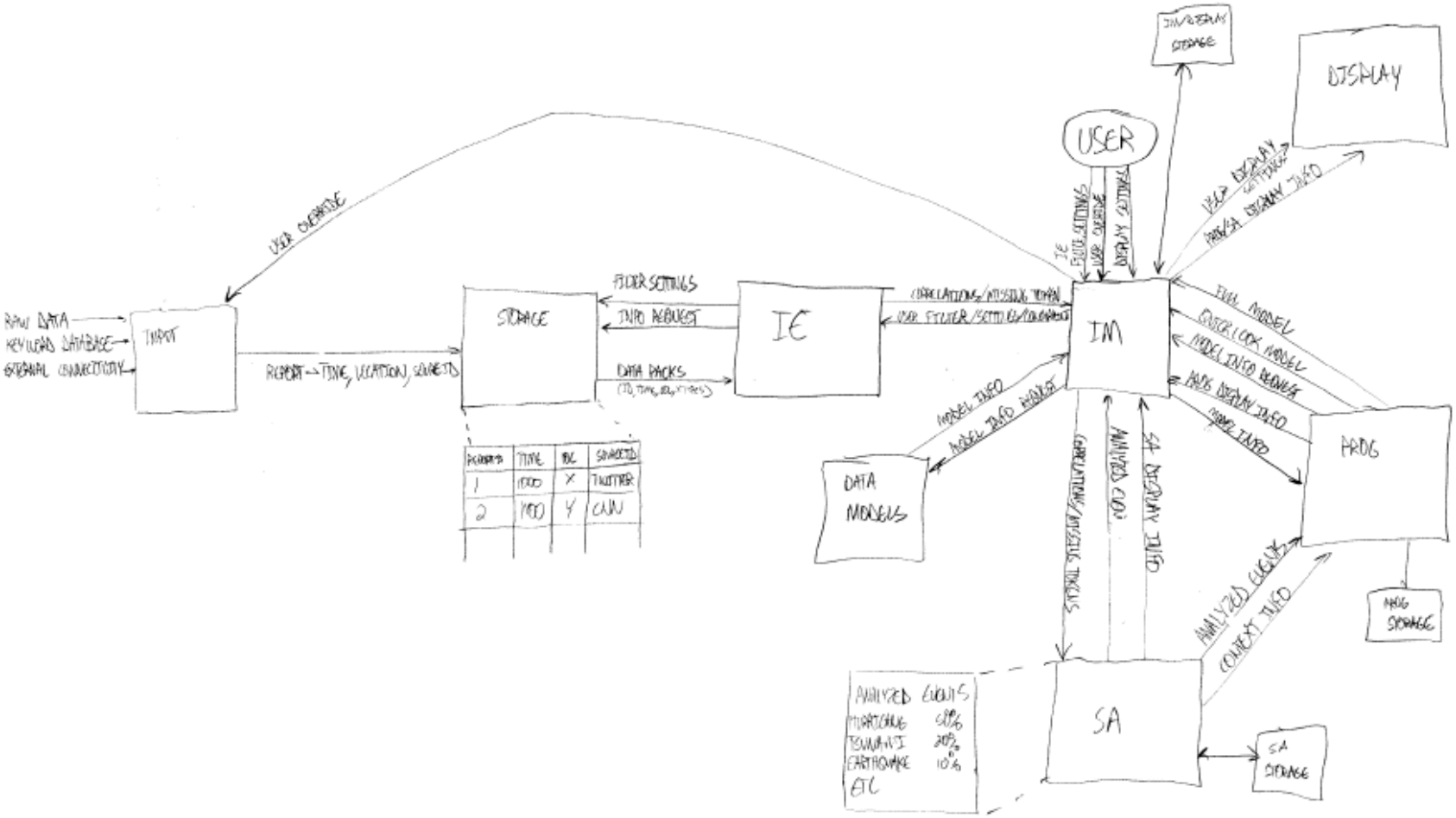
TABLE OF CONTENTS

N-squared Chart Perspective of Developing Requirements

Capture Source Documents	Requirements	Required Capability	Mission Parameters	Outputs		External Interfaces, Compliance Documents	Mission Requirements	Re
	Develop Ops Concept	Operations	Scenarios	Equipment Experience		Organization & Personnel		Re
Input	Elements	**Functional Analysis**	Functional Sequences, Timelines	Functional Areas	Required Functionality		Required Capability	De Re
			Simulation	Sizing	Sizing		Quantified Performance Capability	P
			Configuration	**System Architecture**	Candidate Approaches		Configuration Item Definition	Alt
				Selected Design	**Trade Studies**		Quantified Performance	C Re
Tailored MIL-STDs & MIL-SPECs				Ops Environment, GFE, Cost	Cost	**Design Constraints**	Interface Requirements	Er
Verification of Compliance			Margins & Deficiencies	Margins & Deficiencies	Adverse Consequences	Margins & Deficiencies	**Performance Evaluation**	Re
Traceability			Functionality	Functionality	Baseline Capability Required	Traceability of Flowdown	Required Capability	**Re D**



System Concept Design



System Modeling - FFBD