Air Force Institute of Technology

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A SYSTEMS ARCHITECTURAL MODEL FOR MAN-PACKABLE/OPERABLE ISR MINI/MICRO AERIAL VEHICLES

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Presented By

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Air Force Center for
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Overview

- **Introduction**
  - *Research Goal, Scope and Assumptions*
- **Background**
  - *User, UAV/MAVs, Systems Engineering*
- **Methodology**
  - *DoD Architecture Framework*
- **Results**
  - *Architecture Products, and Future Capabilities*
- **Conclusion**
  - *Concluding Remarks*

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Introduction

- **Research Goal**

  Apply good systems engineering principles to develop a baseline Mini/Micro Aerial Vehicle (MAV) architectural model describing their use in three separate but closely related Intelligence, Surveillance, and Reconnaissance (ISR) mission areas:

  - Over-the-Hill-Reconnaissance
  - Battle Damage Information (BDI)
  - Local Area Defense (LAD)

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Introduction

- **Scope**
  - The Three ISR Mission Areas Define the Application of MAVs for this Thesis

    Scope: MAV can be thought of a single man-packable and single man-operable system that does not require the carrier to sacrifice normal mission essential gear in place of the MAV system.
- **Assumptions**
  - Used by small tactical teams synonymous with special operations forces (SOF)
  - Primarily used for close-in (~<3km range) tactical reconnaissance

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Background: Overview

- **Background**
  - *User*
  - *Unmanned Aerial Vehicles (UAV)*
  - *Mini/ Micro Aerial Vehicles (MAV)*
  - *Systems Engineering (SE)*

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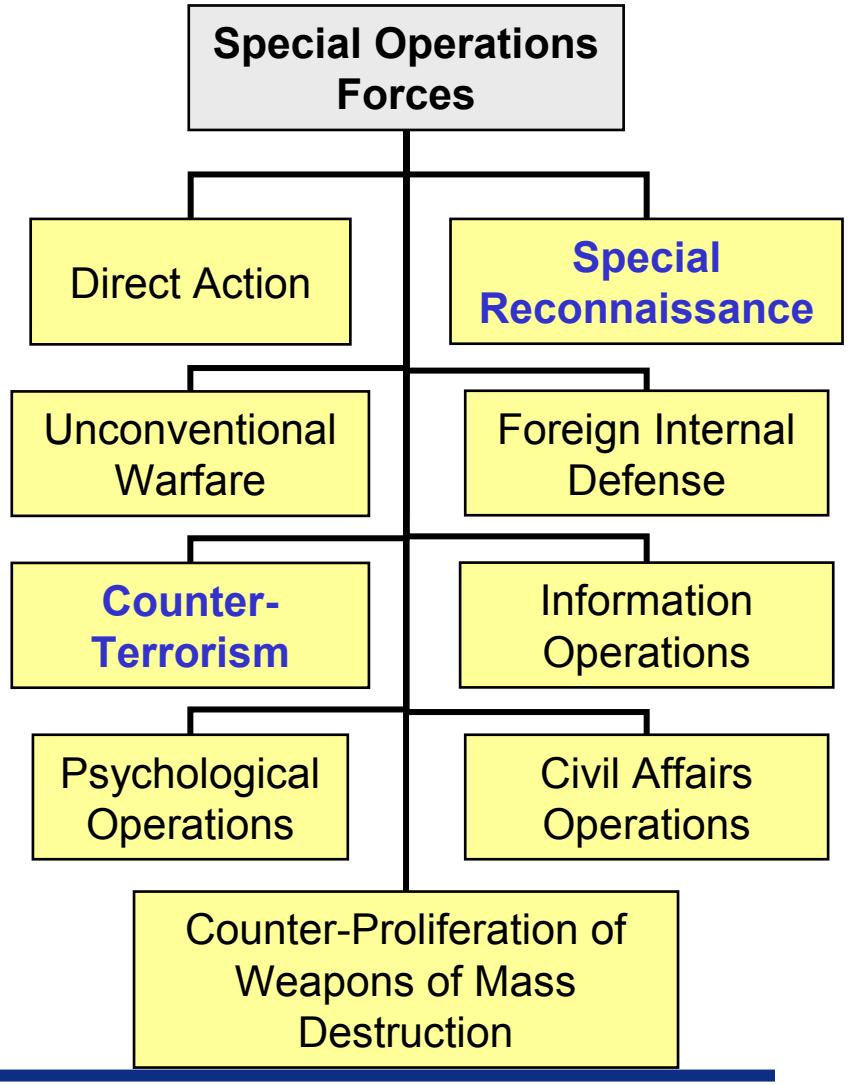
Background: User

- **Special Operations Forces (SOF) conduct fast, surgical operations at great distances from established bases by using state-of-the-art communications, aircraft, and specially trained forces**
- **Responsible for nine principal missions or core tasks ⇒**



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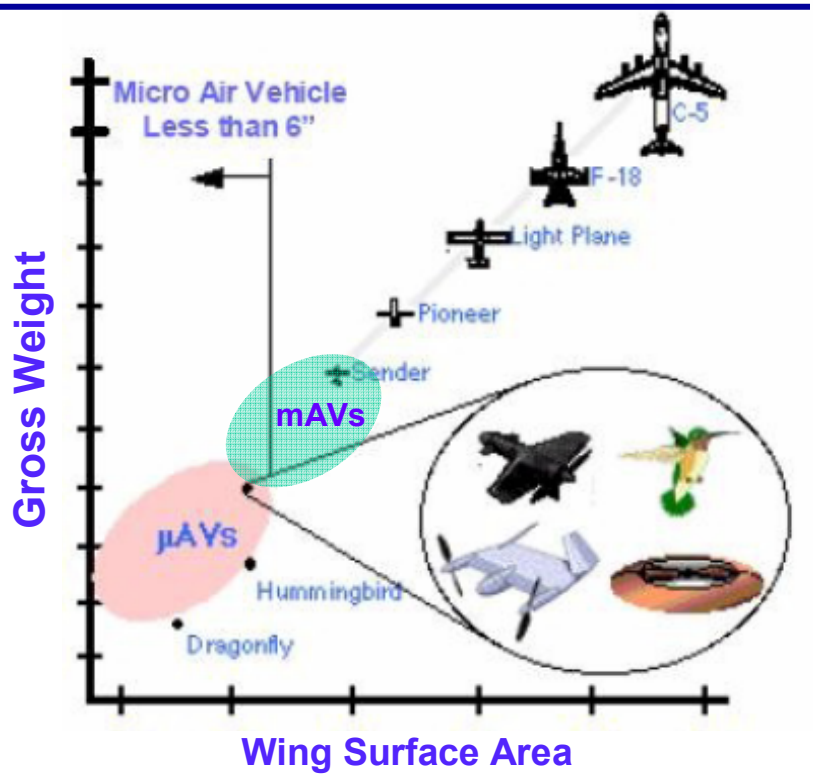
Background: MAVs

- Unmanned Aerial Vehicles (UAVs) include aerial vehicles that can operate using pre-programmed data and those that can accept mission changes while in flight

- Subsets of Mini and Micro Aerial Vehicles (MAVs) are closely related
  - Mini Aerial Vehicles: scale of hobbyist remote controlled aircraft
  - Micro Aerial Vehicles: scale of small birds and dragonflies
- MAV's introduce new challenges
  - Miniaturization of flight and sensor components



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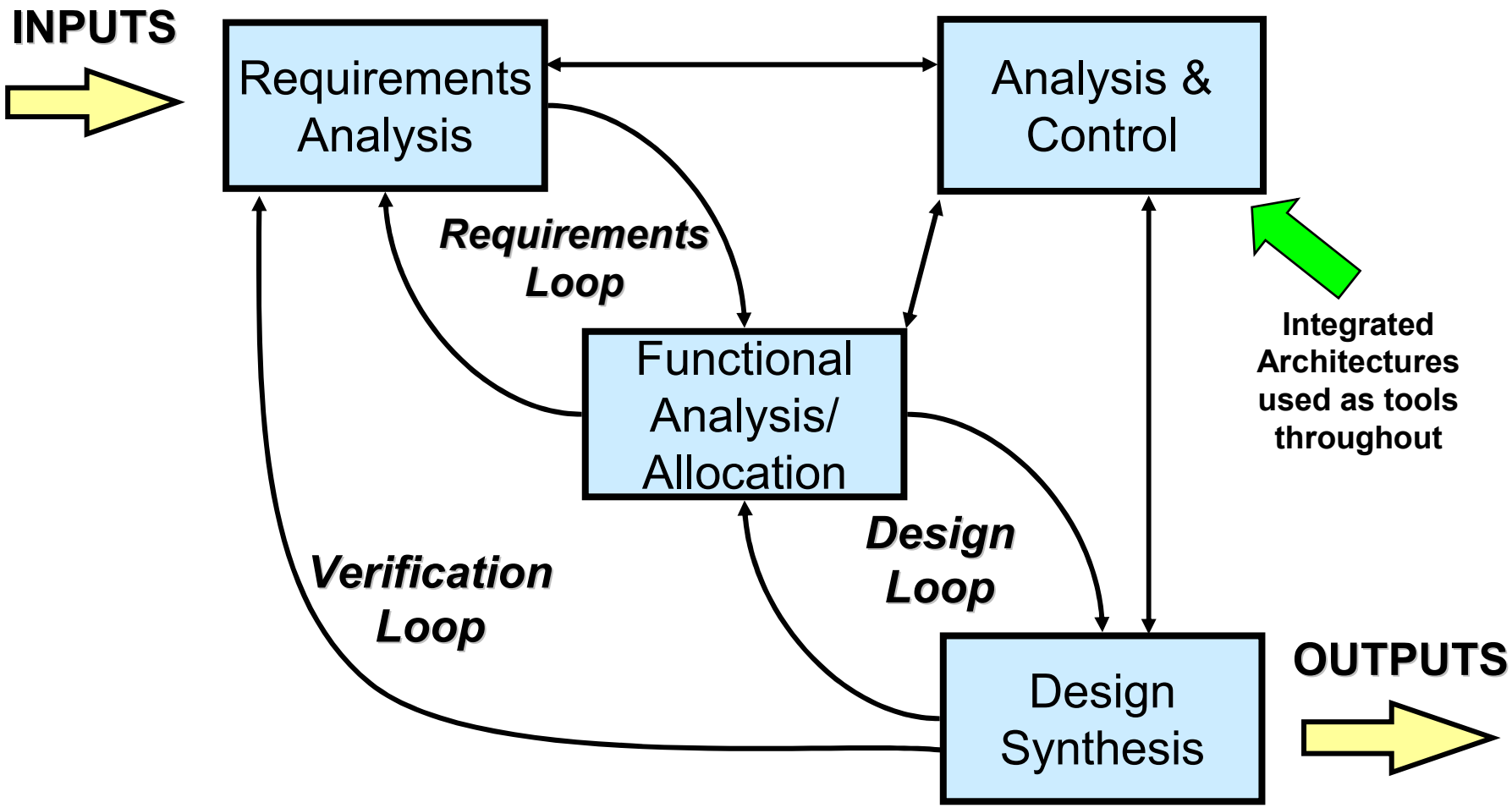
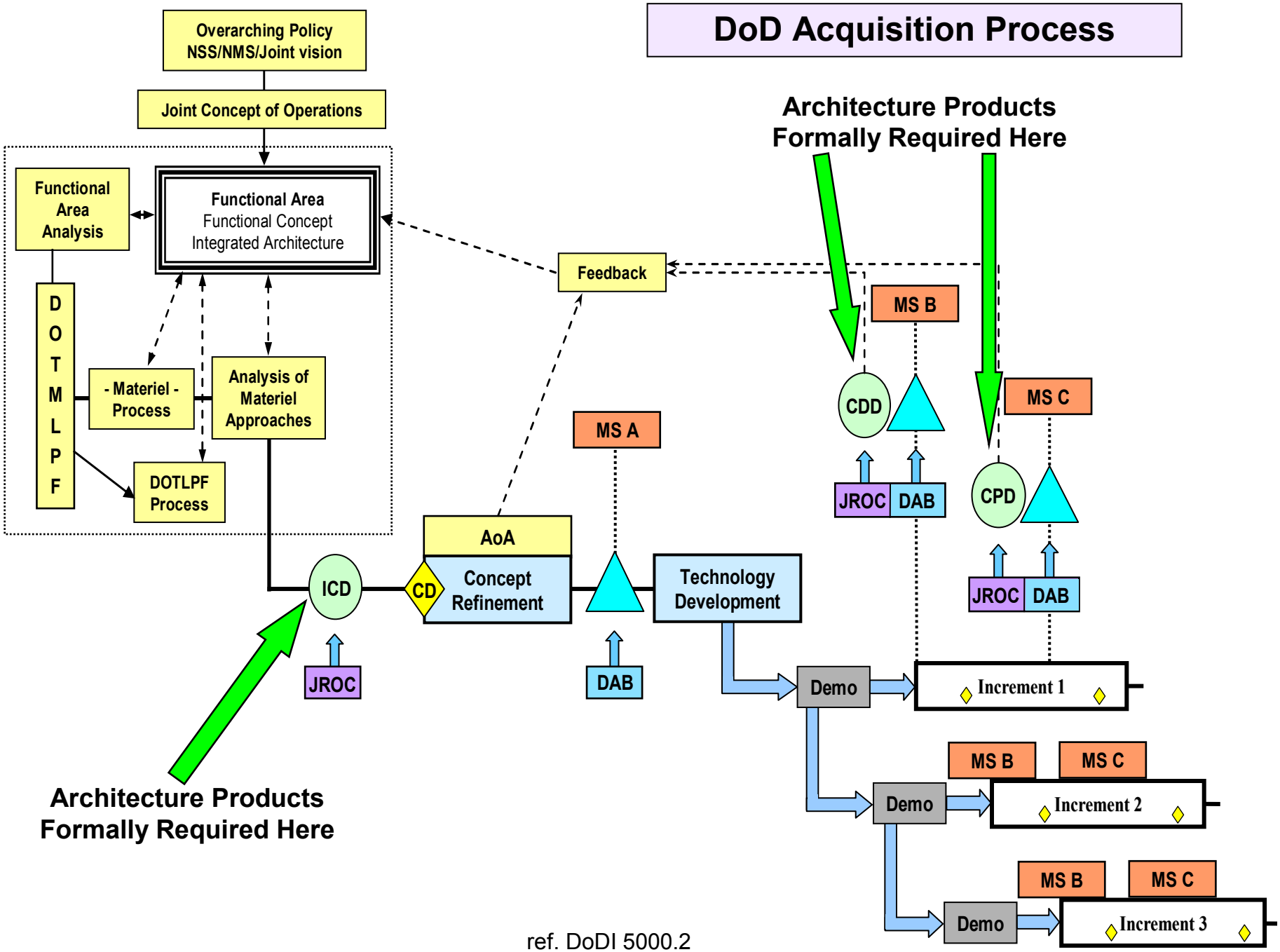
Background: Systems Engineering





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Methodology: Overview

- **Methodology**
  - *DoD Architecture Framework*
  - *Architecture Products*

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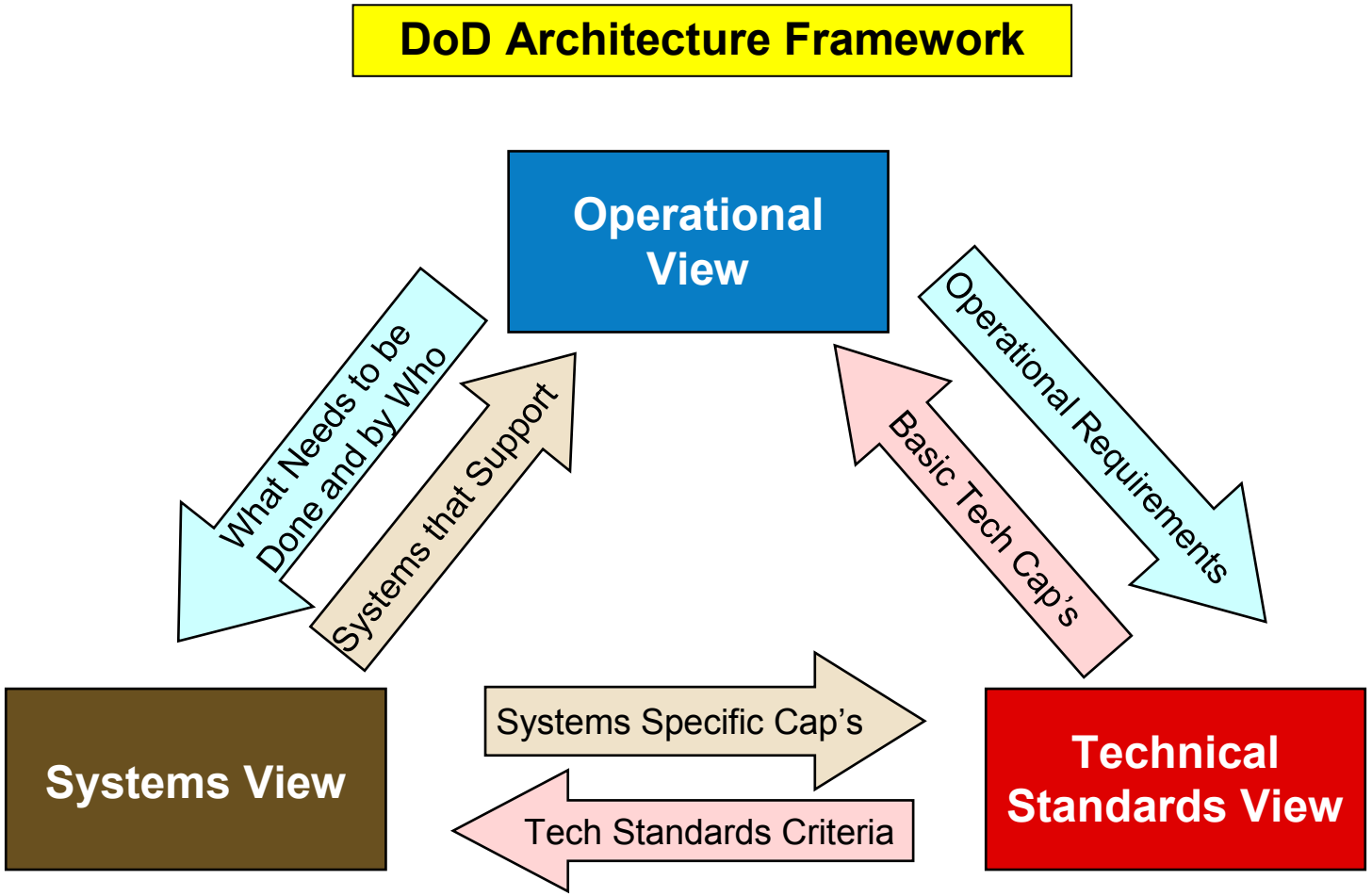
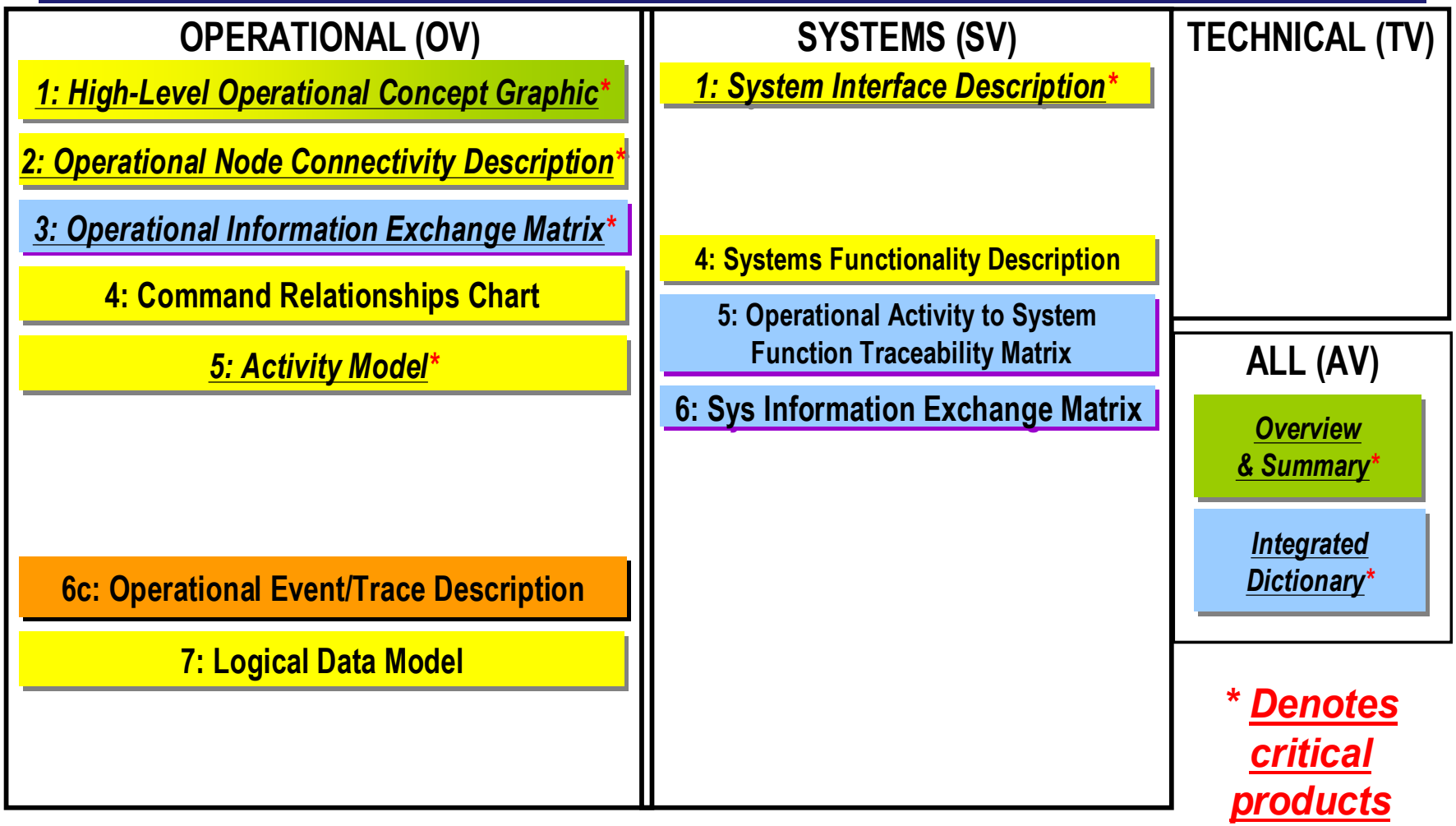
Methodology: Integrated Architectures



Methodology: Products



* Denotes critical products

Spreadsheets | Static Models & Graphics | Text | Dynamic Models

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Results: Overview

- **Results**
  - *Current Baseline or "AS-IS" Architecture Products*
  - *Future Capabilities*

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Results: Operational Scenario's

- Over-the-Hill Reconnaissance
  - Provide enhanced Situational Awareness
  - Identify enemy location/strength
  - Identify enemy armament
- Battle Damage Information
  - Provide feedback on strike success
- Local Area Defense
  - Locate potential/attacking threats
  - Provide relative position
  - Follow retreating enemy
- All missions assume "close-in" deployment
- MAV flown in auto or manual mode

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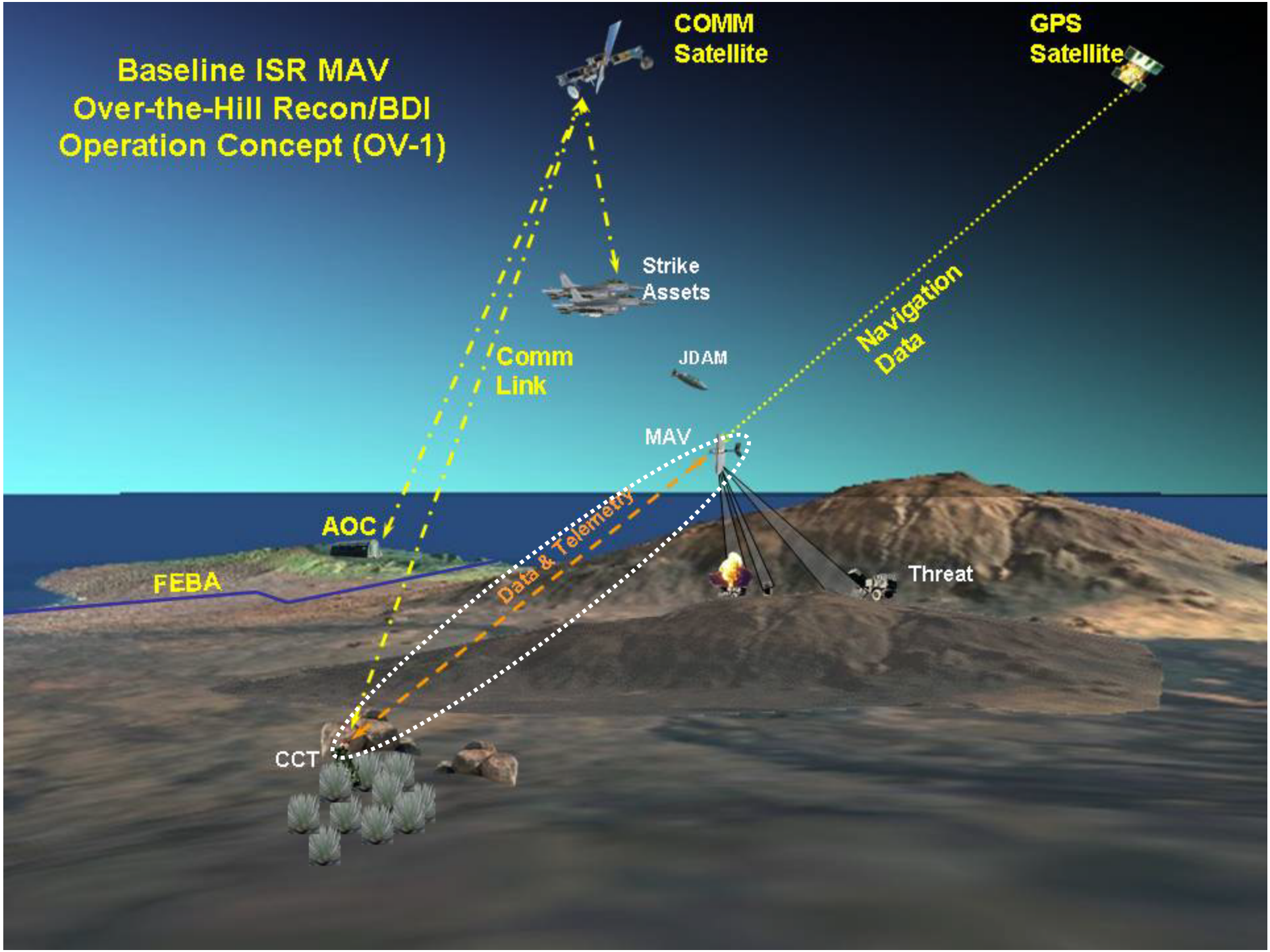
Results: OV Architectures

- Operational Views (OV)
  - Identifies what needs to be accomplished and who does it
- OV Products Completed for ISR MAV
  - OV-1: High Level Operational Concept
  - OV-2: Operational Node Connectivity
  - OV-3: Operational Information Exchange Matrix
  - OV-4: Organizational Relationships Chart
  - OV-5: Operational Activity Model
  - OV-6c: Operational Event Trace Diagram
  - OV-7: Logical Data Model


Baseline ISR MAV
Over-the-Hill Recon/BDI
Operation Concept (OV-1)
COMM
Satellite
GPS
Satellite
Strike
Assets
Comm
Link
JDAM
Navigation
Data
MAV
AOC
FEBA
Data & Telemetry
Threat
CCT

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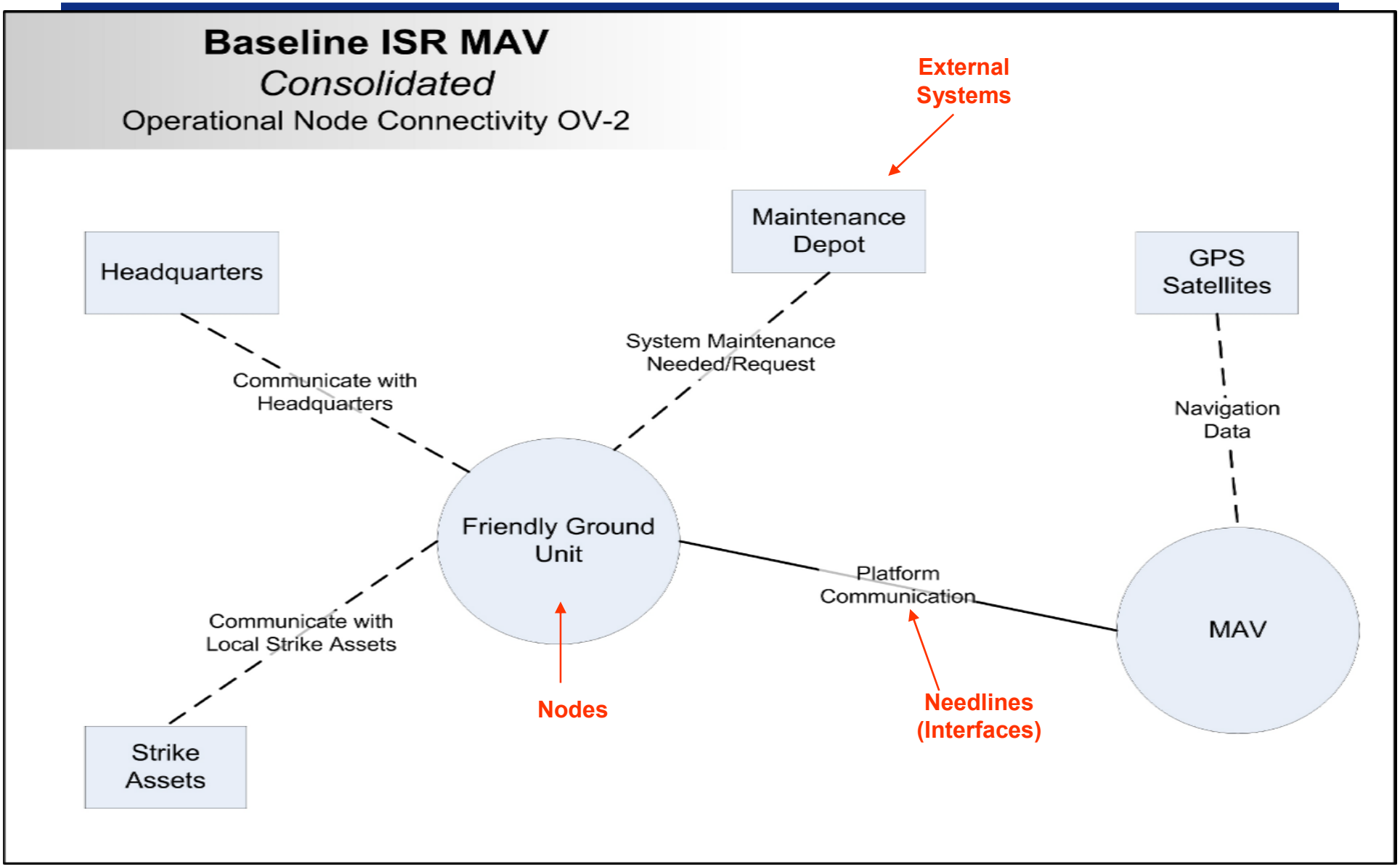
Results: OV Architectures



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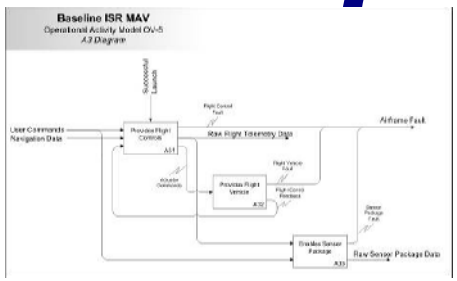
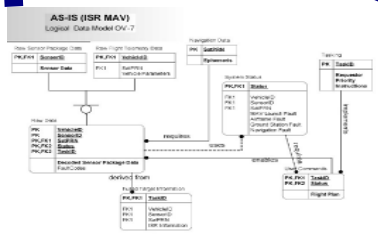
Results: OV Architectures

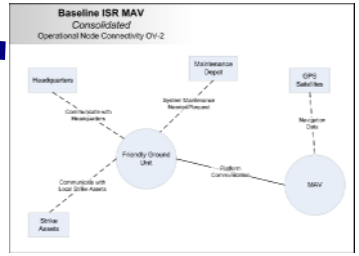
- **OV-3 – Operational Info Exchange Matrix**
- **Details info exchanges**
  - **who, what, why, & how**
- **Includes AFTL references**
- **Expands on info associated with OV-2, OV-5, OV-6C and OV-7**

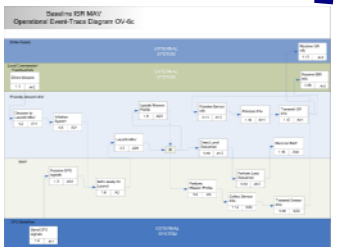
Needline Identifier	Information Exchange Identifier	Information Element Description					Producer		Consumer	
		Information Element Name and Identifier	Content	Scope	Accuracy	Language	Sending Op Node Name and Identifier	Sending Op Activity Name and Identifier	Receiving Op Node Name and Identifier	Receiving Op Activity Name and Identifier

Needline Identifier	Information Exchange Identifier	Nature of Transaction					Performance Attributes		Information Assurance					Security			
		Mission/Scenario UJTL or METL	Transaction Type	Triggering Event	Interoperability Level Required	Criticality	Periodicity	Timeliness	Access Control	Availability	Confidentiality	Dissemination Control	Integrity	Accountability	Protection (Type Name, Duration, Date)	Classification	Classification Caveat

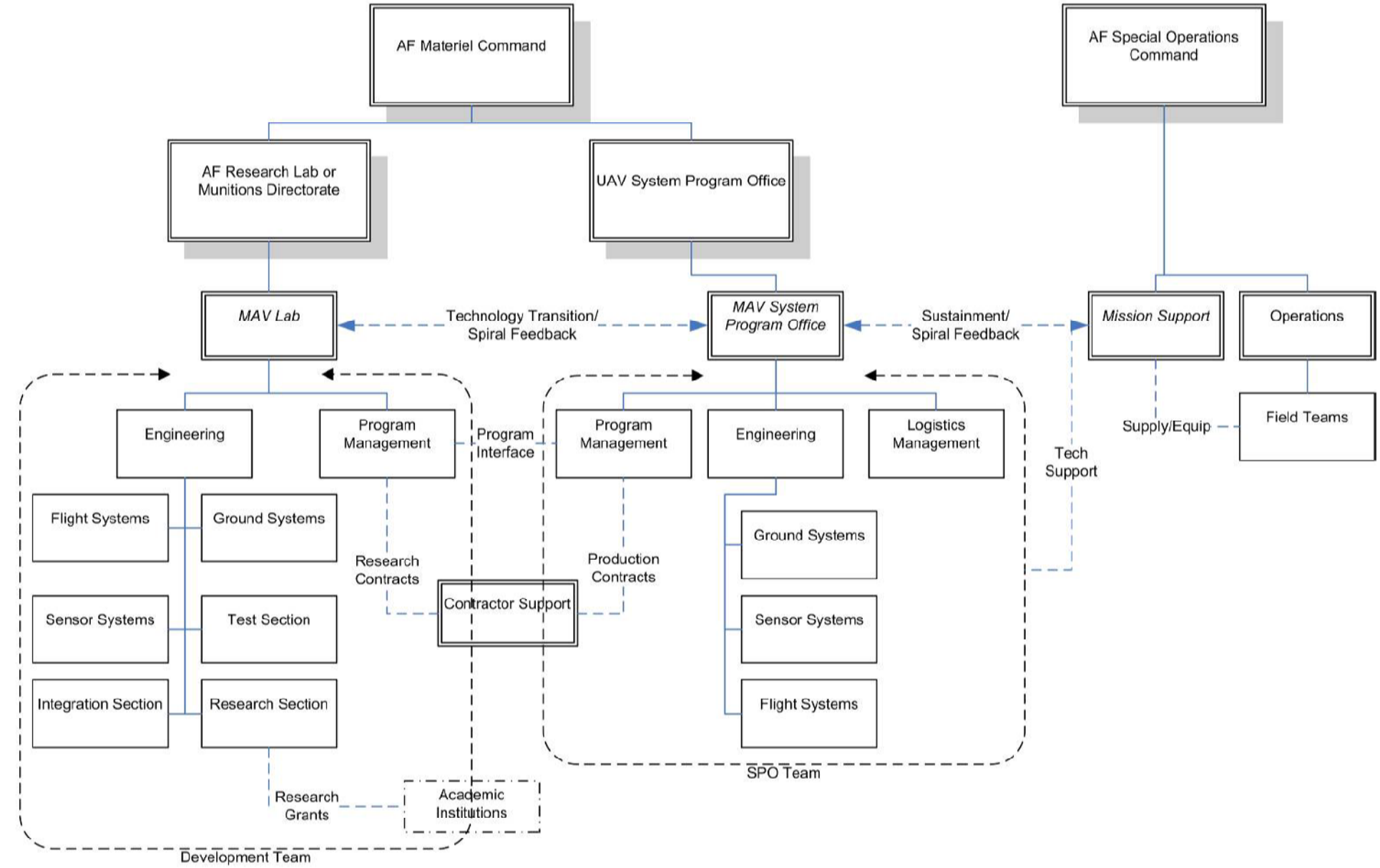








Baseline ISR MAV
OV-4 Organizational Relationships Chart



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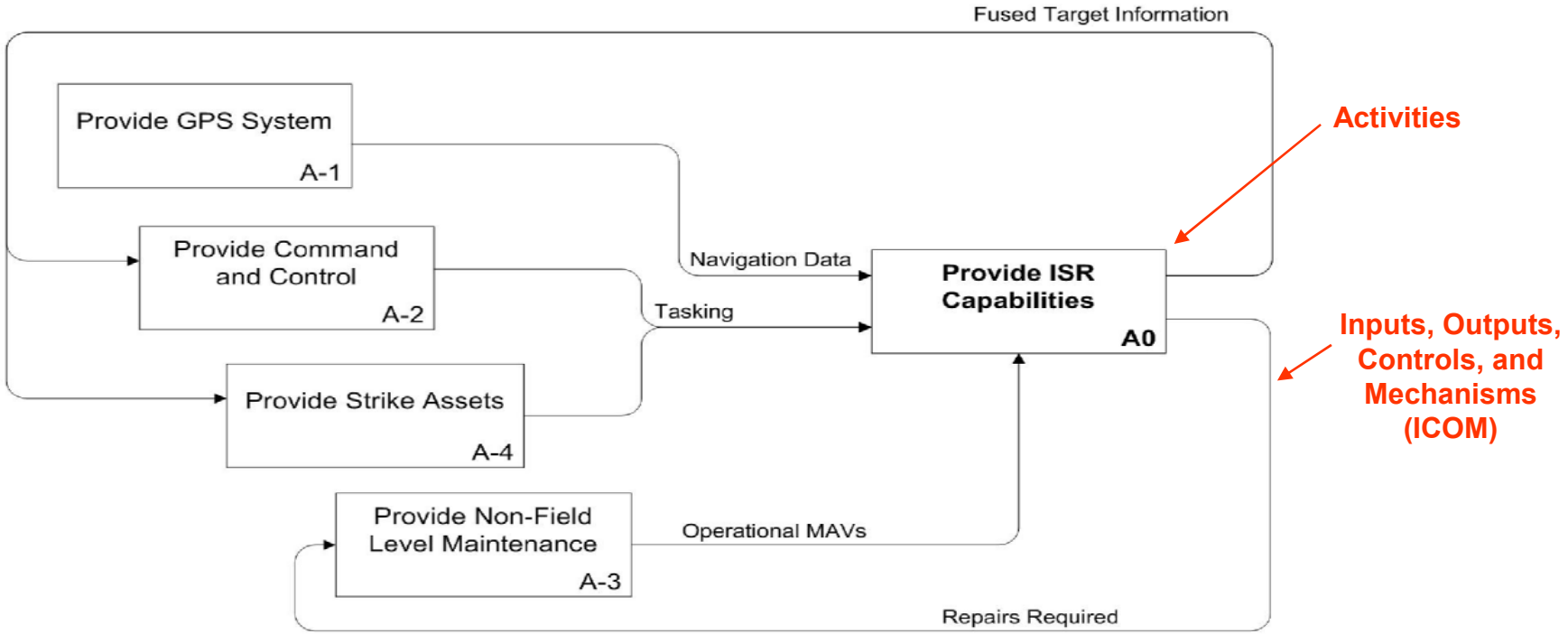
Results: OV Architectures

Baseline ISR MAV

Operational Activity Model OV-5

External Systems Diagram A-1



Purpose: To provide ground forces with a single-man packable, single-man operable ISR capability.
Viewpoint: Operator

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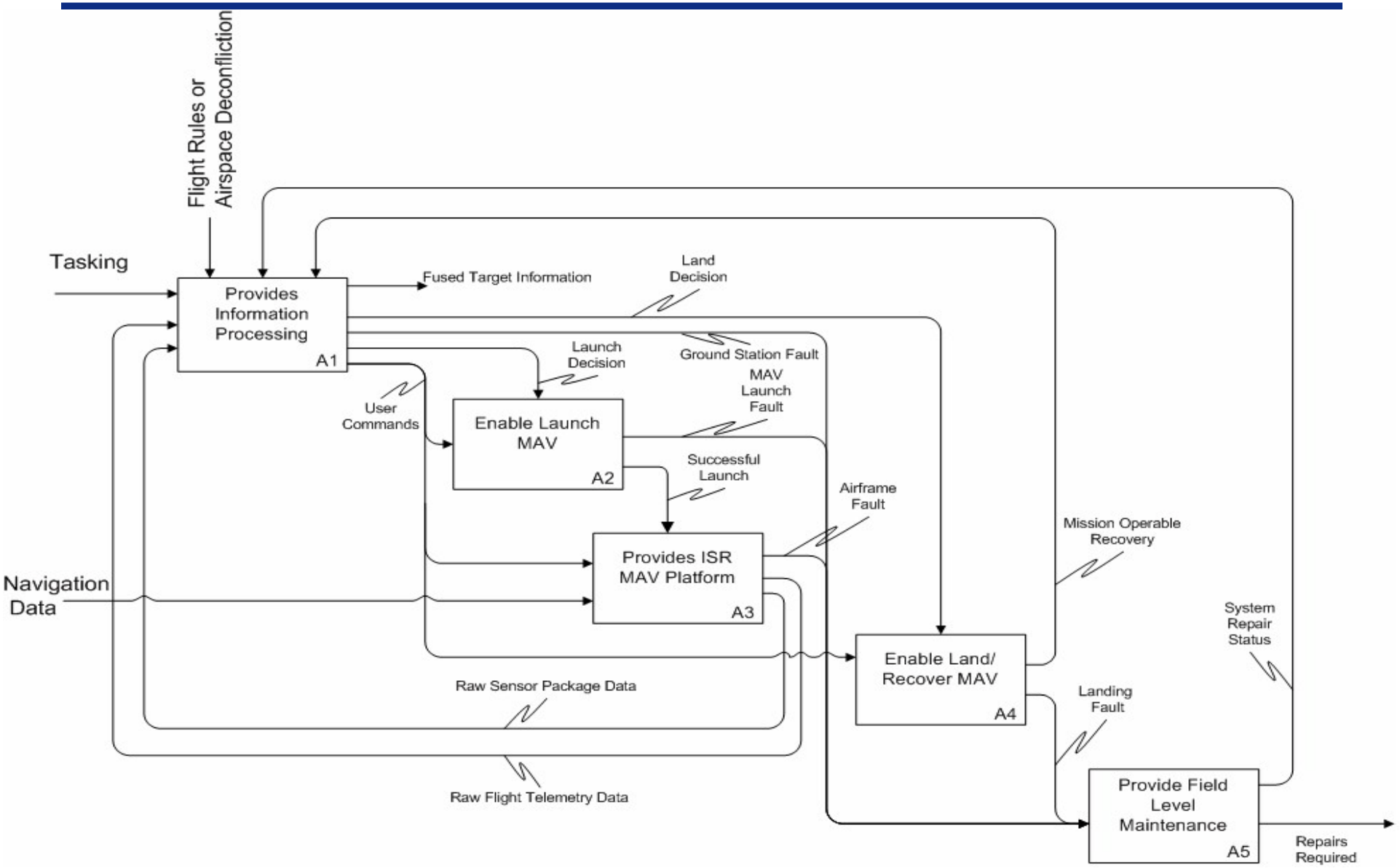
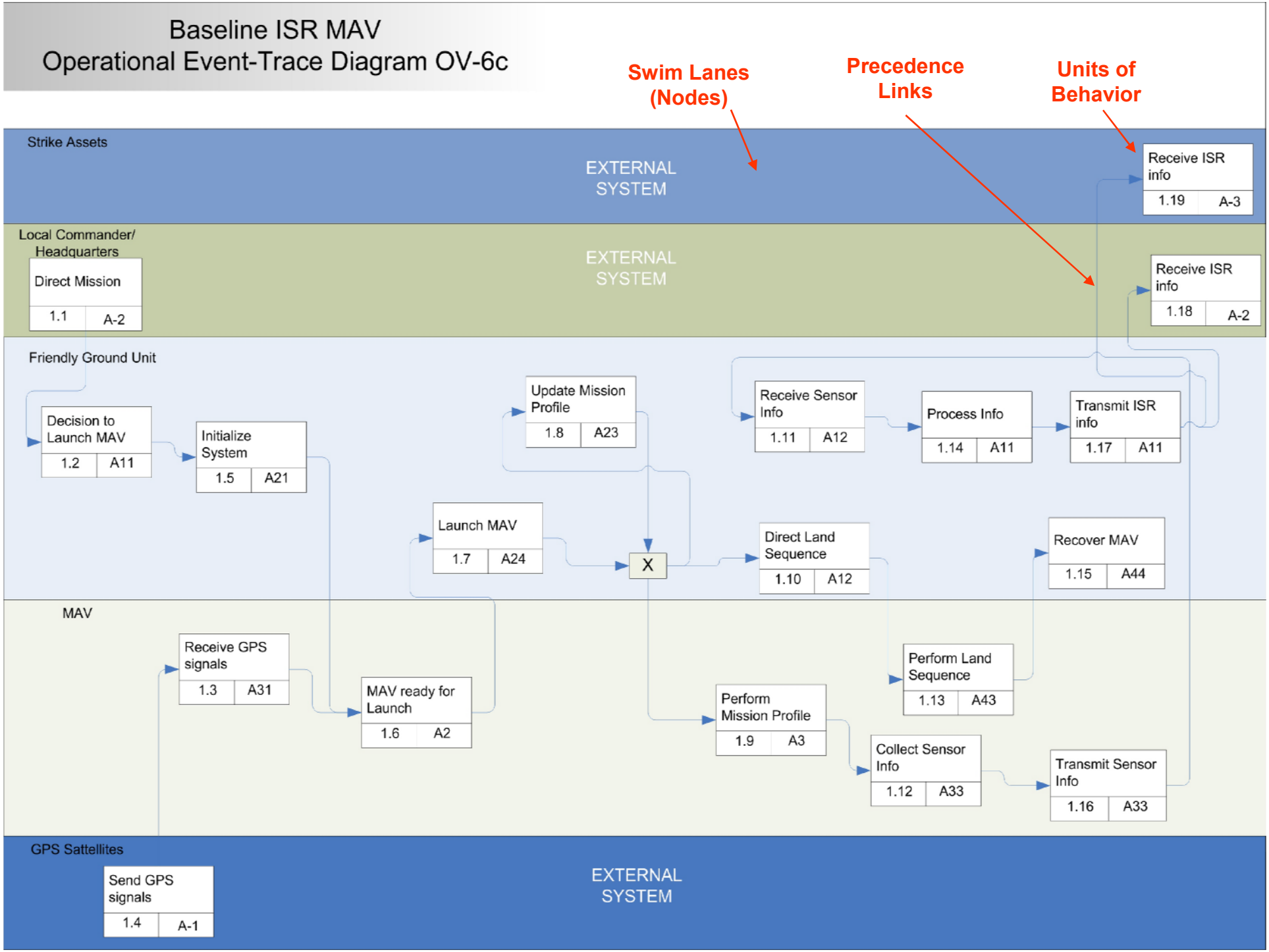
Results: OV Architectures




Baseline ISR MAV
Operational Event-Trace Diagram OV-6c
Swim Lanes (Nodes)
Precedence Links
Units of Behavior
Strike Assets
EXTERNAL SYSTEM
Receive ISR info
1.19
A-3
Local Commander/ Headquarters
EXTERNAL SYSTEM
Direct Mission
1.1
A-2
Receive ISR info
1.18
A-2
Friendly Ground Unit
Decision to Launch MAV
1.2
A11
Initialize System
1.5
A21
Update Mission Profile
1.8
A23
Receive Sensor Info
1.11
A12
Process Info
1.14
A11
Transmit ISR info
1.17
A11
Launch MAV
1.7
A24
X
Direct Land Sequence
1.10
A12
Recover MAV
1.15
A44
MAV
Receive GPS signals
1.3
A31
MAV ready for Launch
1.6
A2
Perform Land Sequence
1.13
A43
Perform Mission Profile
1.9
A3
Collect Sensor Info
1.12
A33
Transmit Sensor Info
1.16
A33
GPS Sattellites
EXTERNAL SYSTEM
Send GPS signals
1.4
A-1

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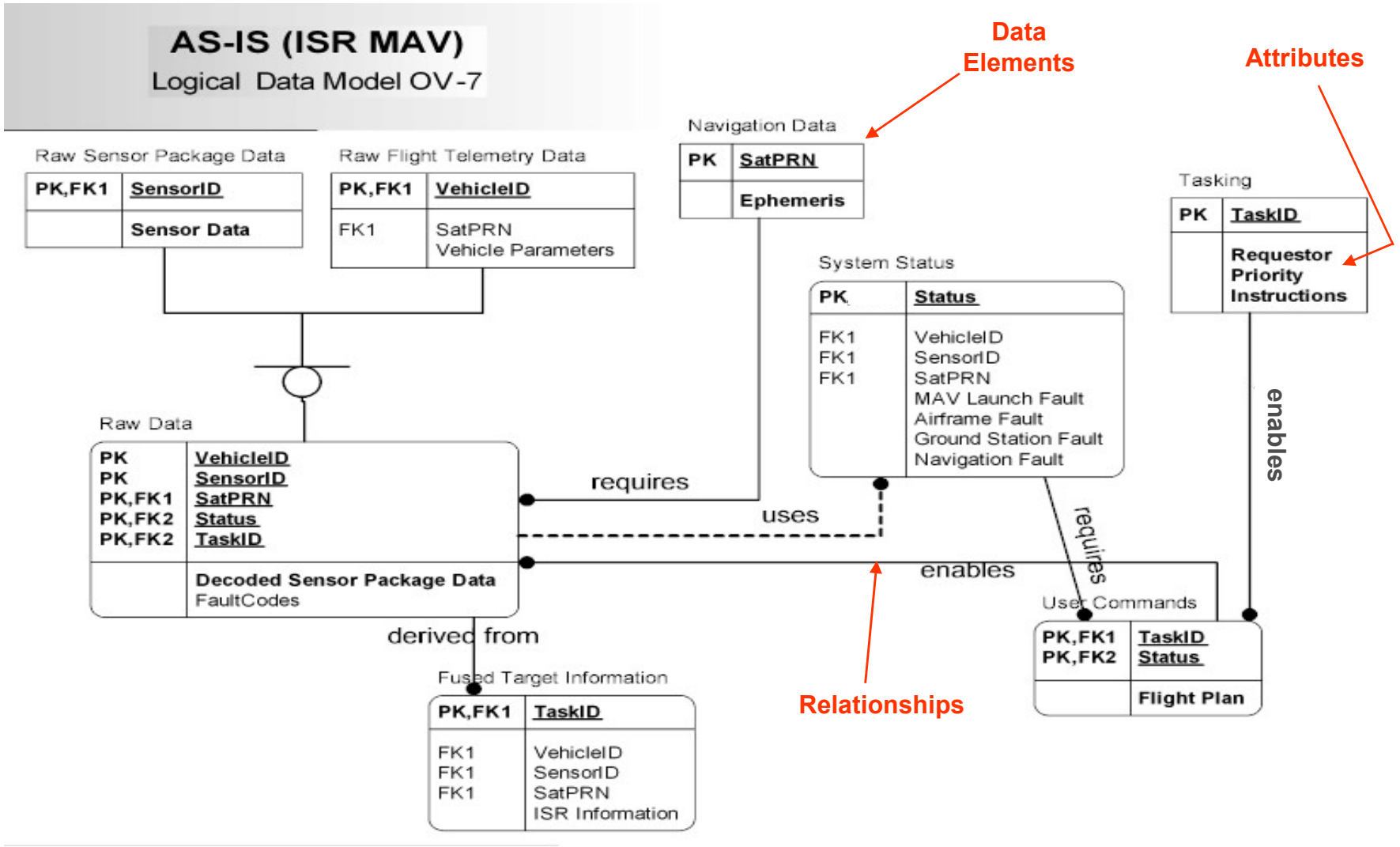
Results: OV Architectures



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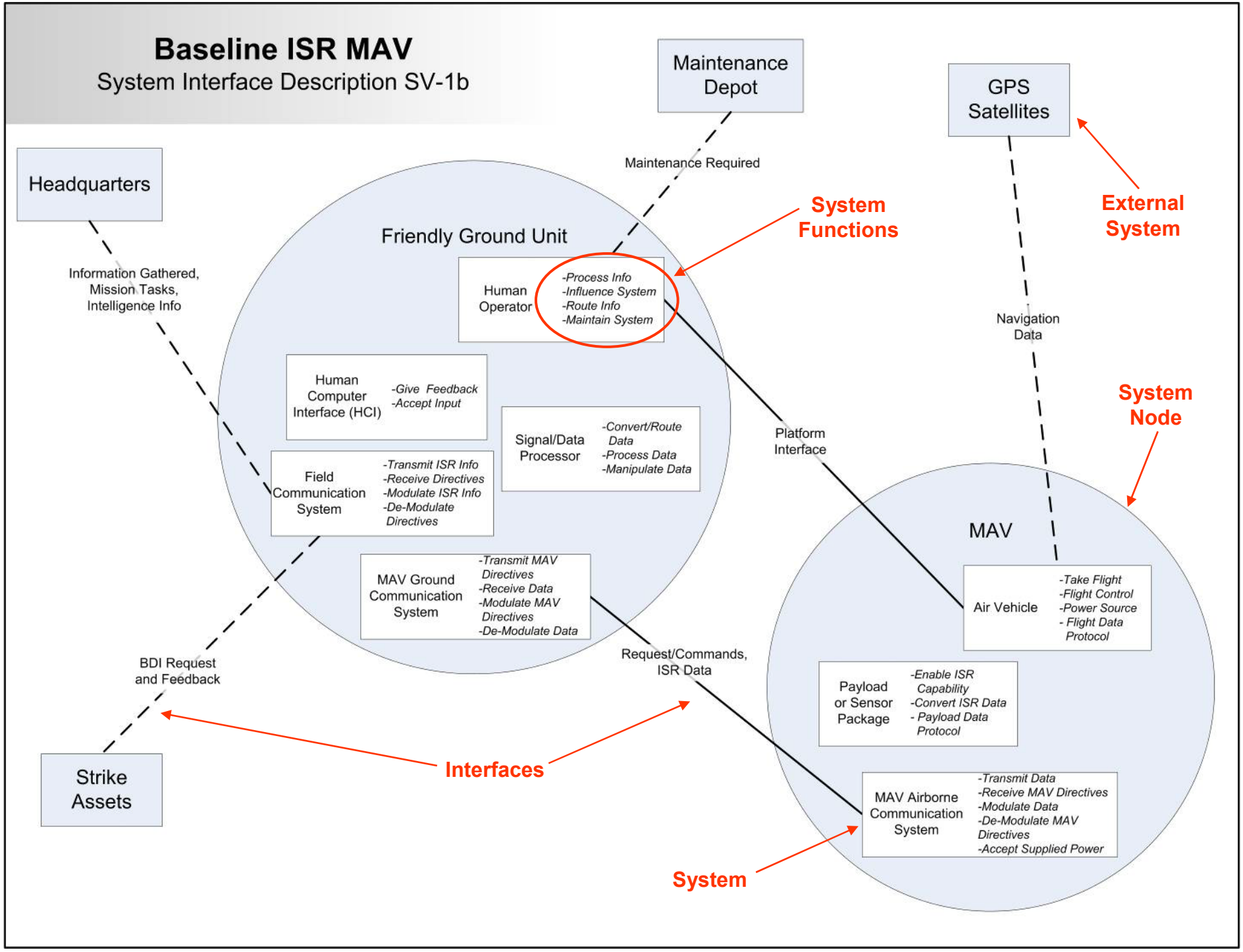
Results: SV Architectures

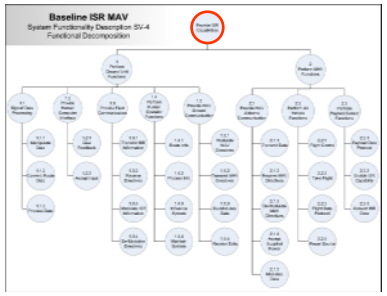
- Systems Views (SV's)
  - Relates Systems and Characteristics to Operational Needs
  - Provides Systems that support OV Activities and Information Exchanges
- SV Products Completed for ISR MAV
  - SV-1: Systems Interface Description
  - SV-4: Systems Functionality Description
  - SV-5: Function to Activity Traceability Matrix
  - SV-6: System Data Exchange Matrix

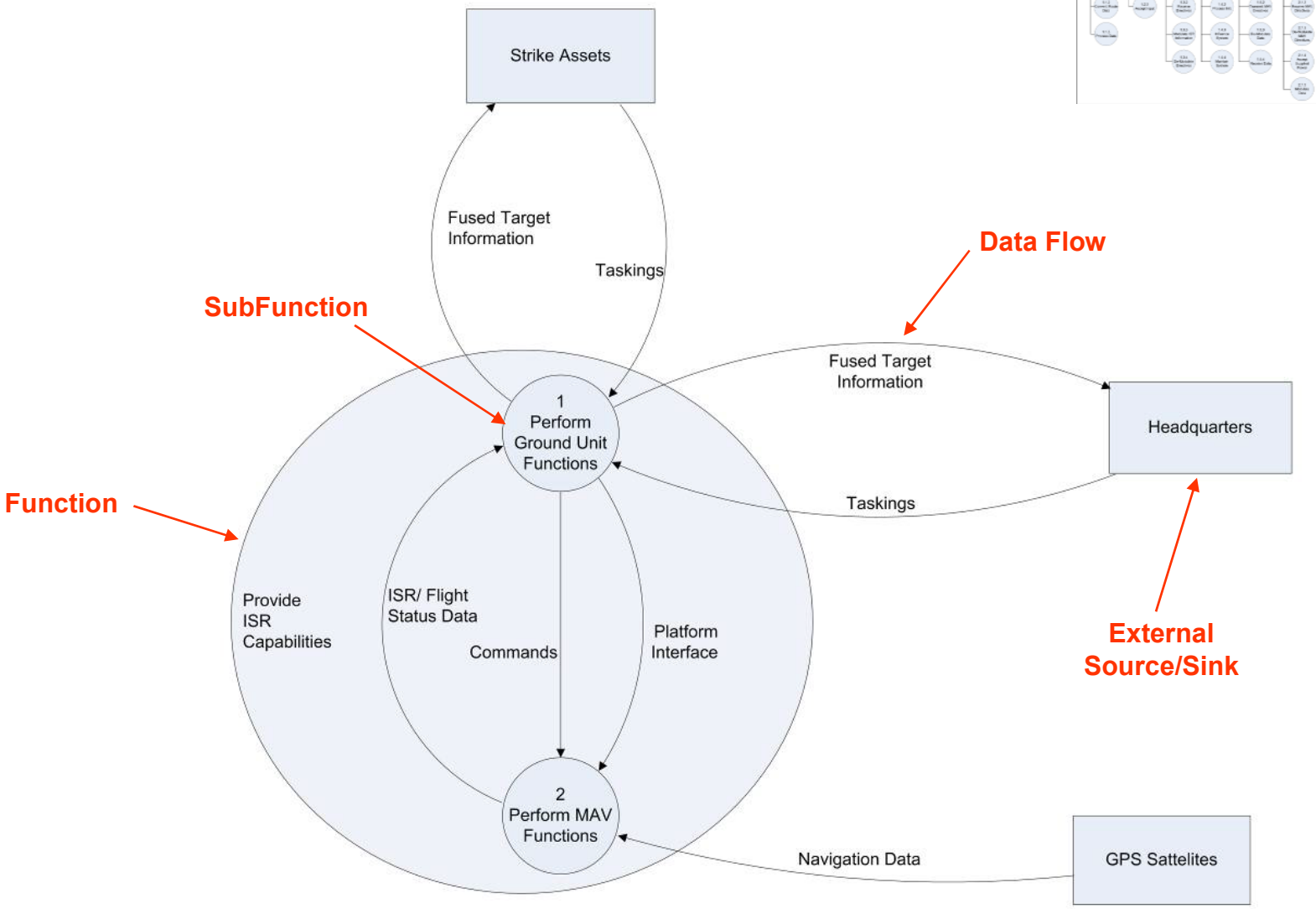

Baseline ISR MAV
System Interface Description SV-1b
Maintenance Depot
GPS Satellites
Headquarters
Maintenance Required
System Functions
External System
Friendly Ground Unit
Information Gathered, Mission Tasks, Intelligence Info
Human Operator
-Process Info
-Influence System
-Route Info
-Maintain System
Navigation Data
Human Computer Interface (HCI)
-Give Feedback
-Accept Input
System Node
Signal/Data Processor
-Convert/Route Data
-Process Data
-Manipulate Data
Platform Interface
Field Communication System
-Transmit ISR Info
-Receive Directives
-Modulate ISR Info
-De-Modulate Directives
MAV
MAV Ground Communication System
-Transmit MAV Directives
-Receive Data
-Modulate MAV Directives
-De-Modulate Data
Air Vehicle
-Take Flight
-Flight Control
-Power Source
- Flight Data Protocol
BDI Request and Feedback
Request/Commands, ISR Data
Payload or Sensor Package
-Enable ISR Capability
-Convert ISR Data
- Payload Data Protocol
Strike Assets
Interfaces
MAV Airborne Communication System
-Transmit Data
-Receive MAV Directives
-Modulate Data
-De-Modulate MAV Directives
-Accept Supplied Power
System

Baseline ISR MAV

System Functionality Description SV-4

0-Level Diagram





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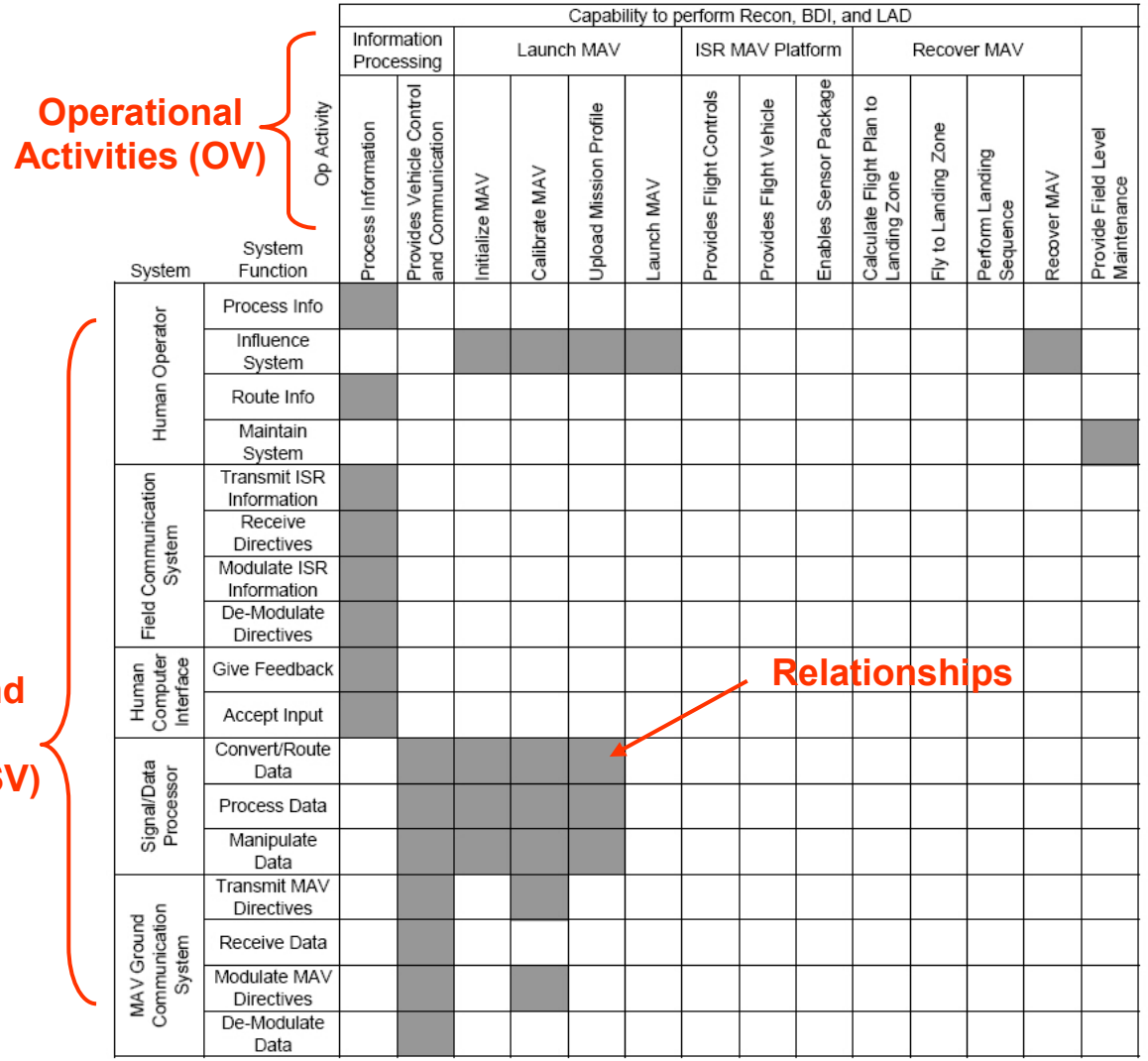
Results: SV Architectures

- **SV-5: Operational Activity to System Function Traceability Matrix**
  - Relationships rated based on support status codes



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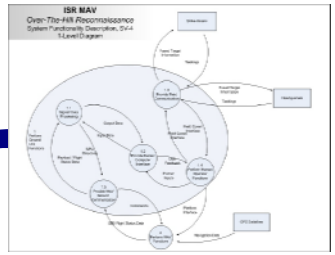
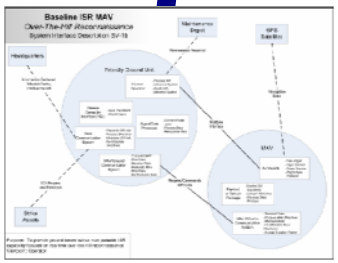
Results: SV Architectures

SV-6: System Data Exchange Matrix

- Specifies characteristics of the system data exchanged between systems
- Focuses on automated information exchanges, however some non-automated exchanges were included
- Columns that were application specific are not filled in





Interface Identifier		Data Exchange Identifier	Data Description						Producer		Consumer		Nature of Transaction			
System Interface Name and Identifier	System Data Exchange Name and Identifier	Data Element Name and Identifier	Content	Format Type	Media Type	Accuracy	Units of Measurement	Data Standard	Sending System Name and Identifier	Sending System Function Name and Identifier	Receiving System Name and Identifier	Receiving System Function Name and Identifier	Transaction Type	Triggering Event	Interoperability Level Achieved	Criticality

Interface Identifier		Data Exchange Identifier	Performance Attributes				Information Assurance						Security			
System Interface Name and Identifier	System Data Exchange Name and Identifier	Periodicity	Timeliness	Throughput	Size	Access Control	Availability	Confidentiality	Dissemination Control	Integrity	Non-Repudiation Producer	Non-Repudiation Consumer	Protection (Type Name, Duration, Date)	Classification	Classification Caveat	Releasability	Security Standard

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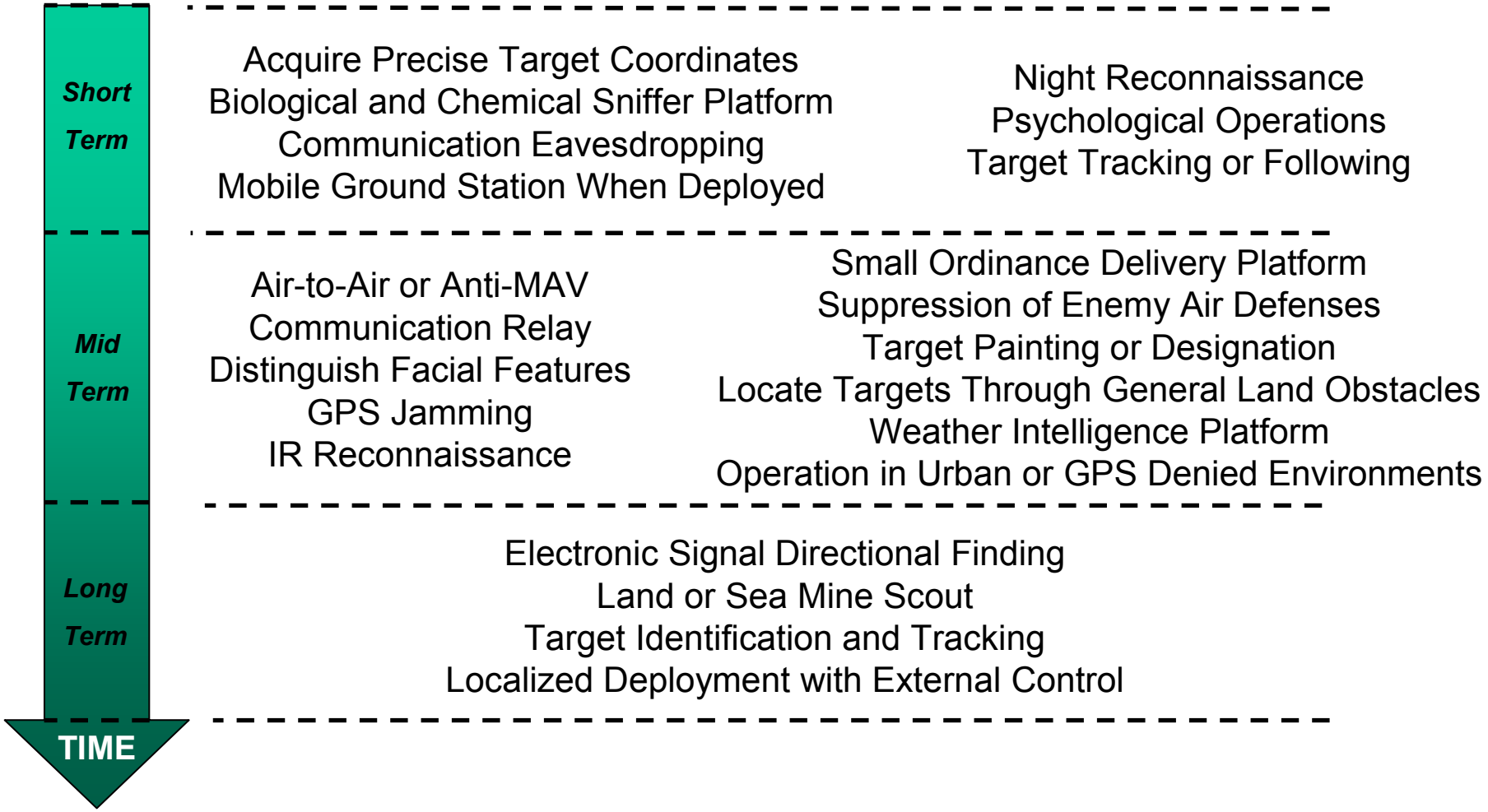
Results: Future Capabilities

Future Capability Timeline:



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Conclusion: Remarks

- MAVs Represent a New Realm of Capability Enablers
- Architectures are Required in the DoD Acquisition Process
- ISR MAVs Now Have a Baseline Architecture
- Requirements Can Now Be Derived from the ISR MAV Architecture (Interfaces, Information Exchanged, Etc.)

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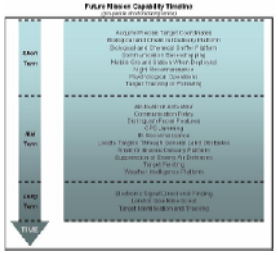
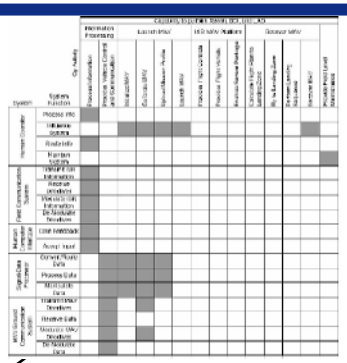
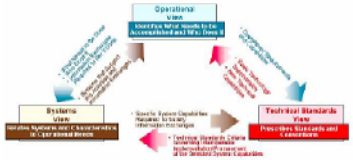
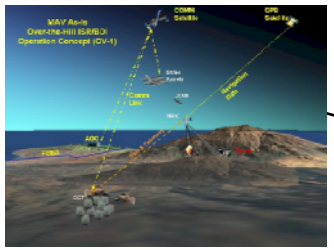
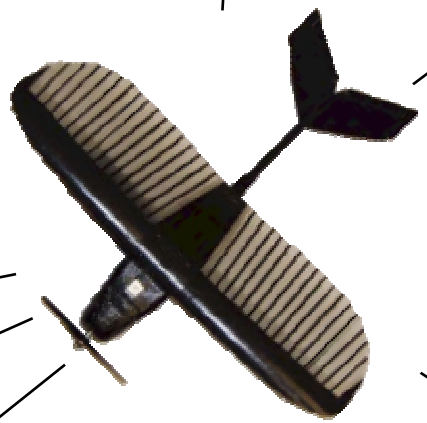
Questions?

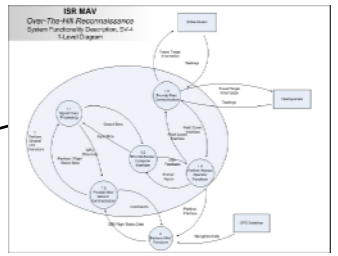


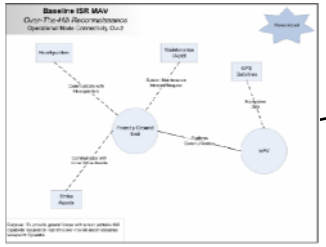


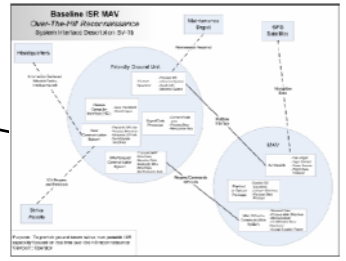


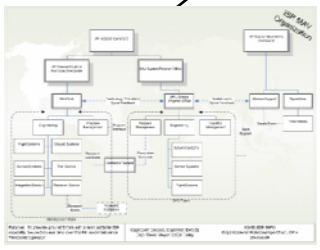


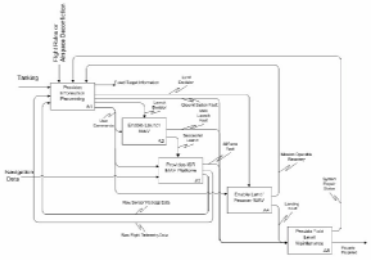


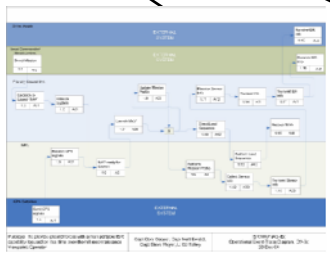


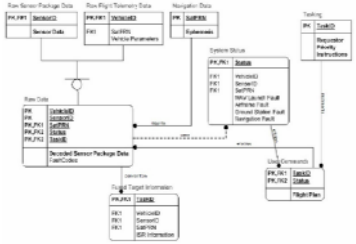












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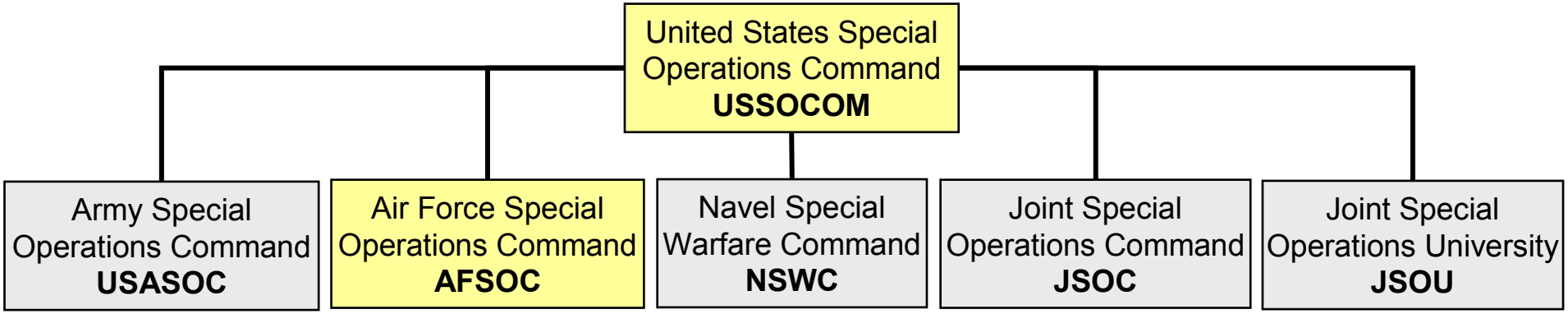
Background: User



Special Operations are those operations conducted in hostile, denied, or politically sensitive environments to achieve military, diplomatic, informational, and/or economic objectives.

Special Operations Forces (SOF) conduct fast, surgical operations at great distances from established bases by using state-of-the-art communications, aircraft, and specially trained forces.

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Background: User

SOF Capability Deficiencies

Domain	*Capability Deficiencies*
Command, Control, and Communications	-Potential for enemy to monitor or destroy our information systems
Intelligence	-No real/near-time imagery from national systems -No real-time interface between aircraft, planners, and intel systems -No real-time imagery for target study -No all-source threat location data -Enhanced target identification and marking capability required
Resupply	-Need resupply of expendables (batteries, food, water, medical, ammo)

Extracted from Maj Stephen Howard's Special Operations Forces and Unmanned Aerial Vehicles

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Background: UAVs

- **Unmanned Aerial Vehicles (UAVs)**
  - Consist of both Remotely Piloted Vehicles (RPVs) and Drones
  - Also encompass those vehicles that can operate using preprogrammed data and can also accept mission changes while in flight
  - Classifications:
    - **Tactical** and Endurance
    - Lethal and **Non-Lethal**
    - **Very Low Cost Close Range**, **Close Range**, Short Range, and Medium Range
    - **Expendable** and Recoverable


RQ-1 Predator


RQ-2A Pioneer

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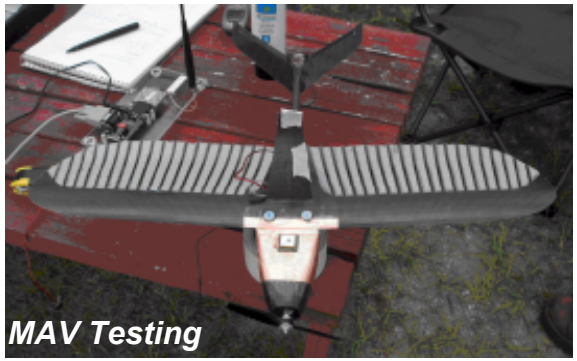
Background: MAVs

- **Mini and Micro Unmanned Aerial Vehicles (MAVs)**
  - + Subset of UAVs characterized by their size
  - + Provides new capabilities to small field units
  - + Not as Expensive as larger UAVs
  - + Changeable Payloads
  - + Small Footprint
  - - Limited Payload Weight
  - - Limited Mission Efficiency (range)
  - - Aerodynamics and Stabilization


Desert Hawk


MAV Testing

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Background: Systems Engineering

- Systems Engineering and Policy
  - Clinger-Cohen Act of 1996 required the DoD to use Architectures for National Security Systems
  - OMB Circulars A-130 and A-11 directed all federal organizations have architecture frameworks
  - CJCSM 3170.01 “Operation of the Joint Capabilities Integration and Development System (JCIDS)” require the use of Integrated architectures for Acquisition Milestones

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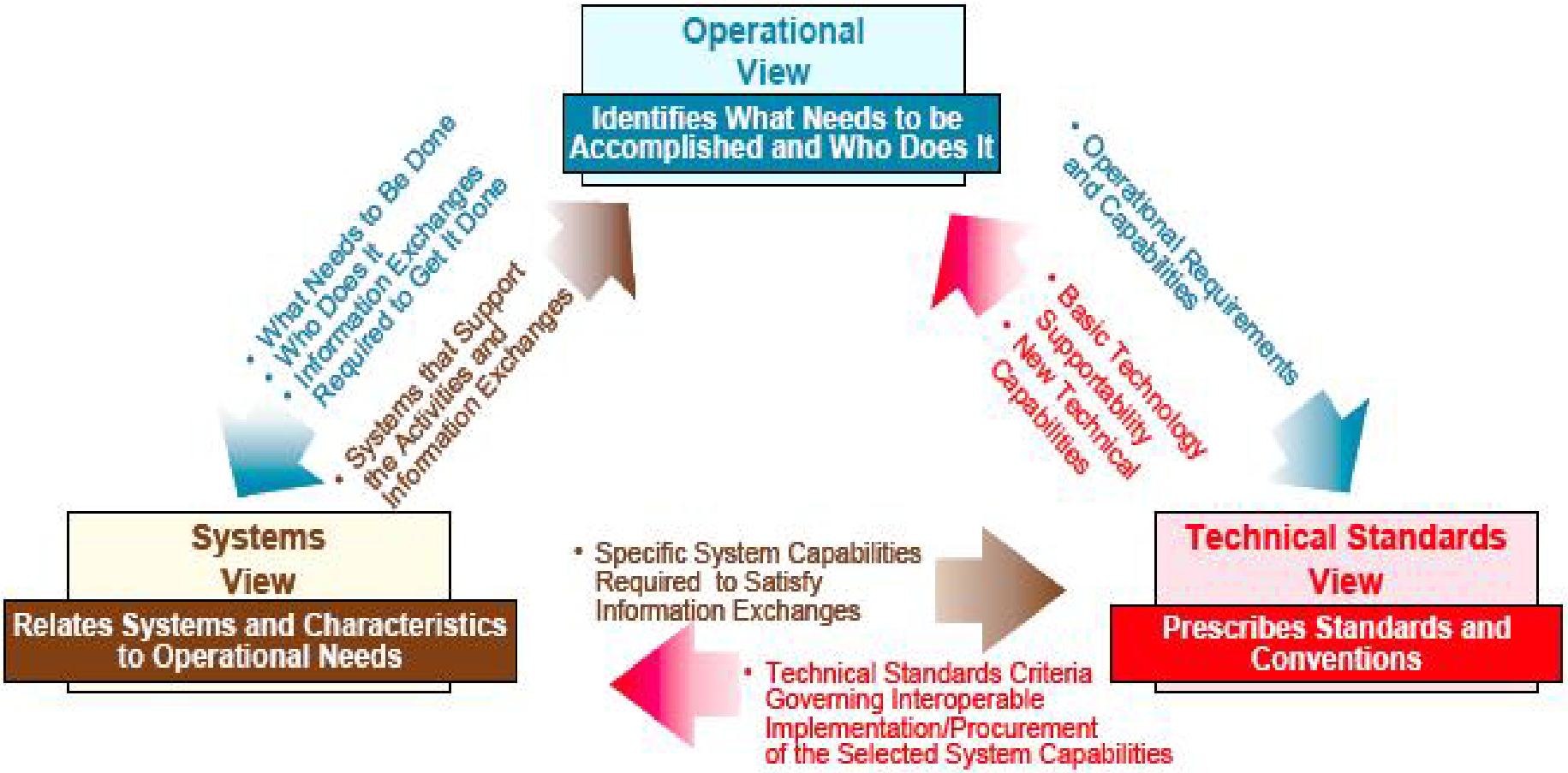
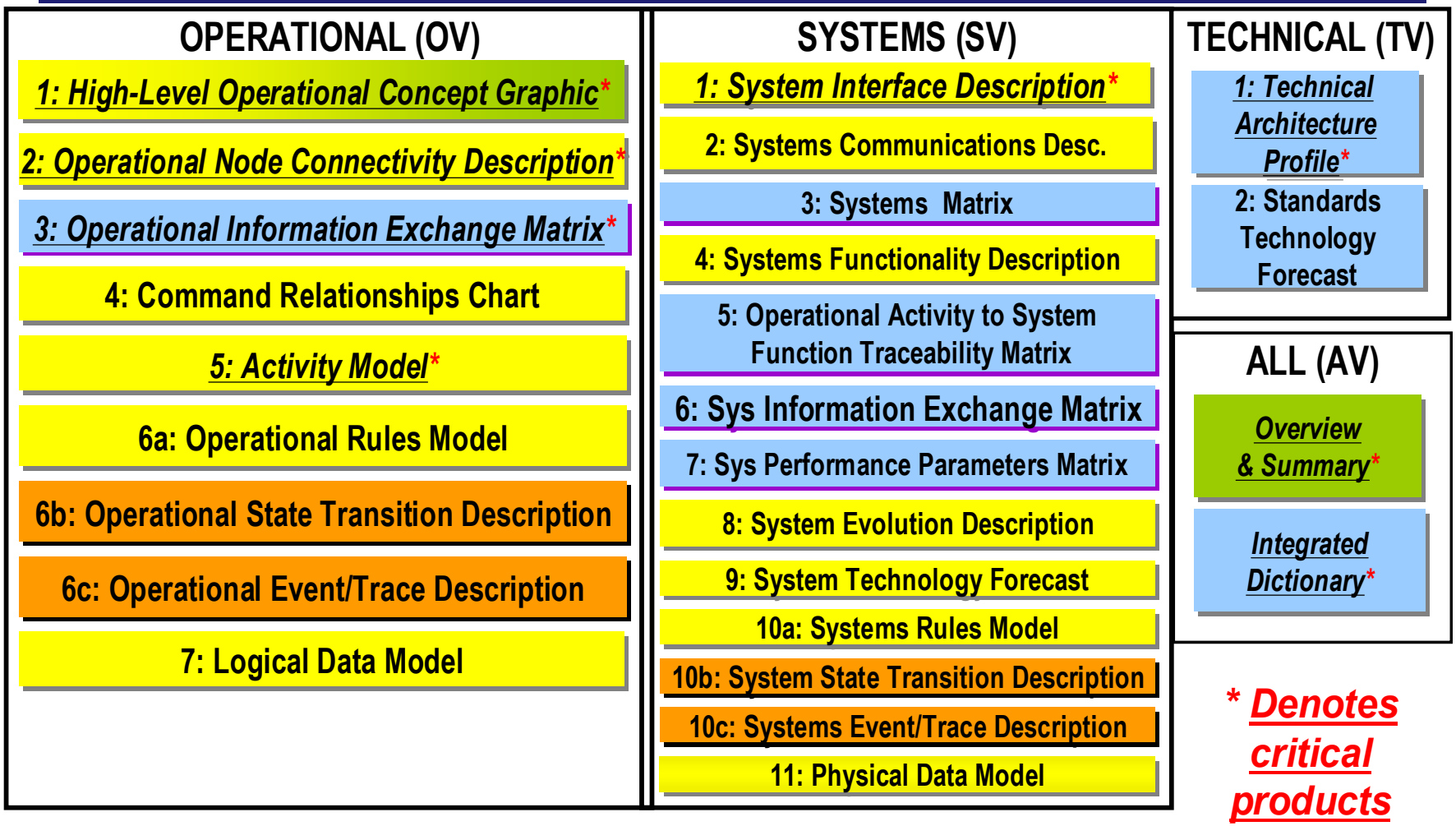
Methodology: Integrated Architectures



Methodology: Products



CADM: Core Architecture Data Model

Spreadsheets | Static Models & Graphics | Text | Dynamic Models

Int ell

ref. AFIT SENG 640 Lesson 1-2 Slides

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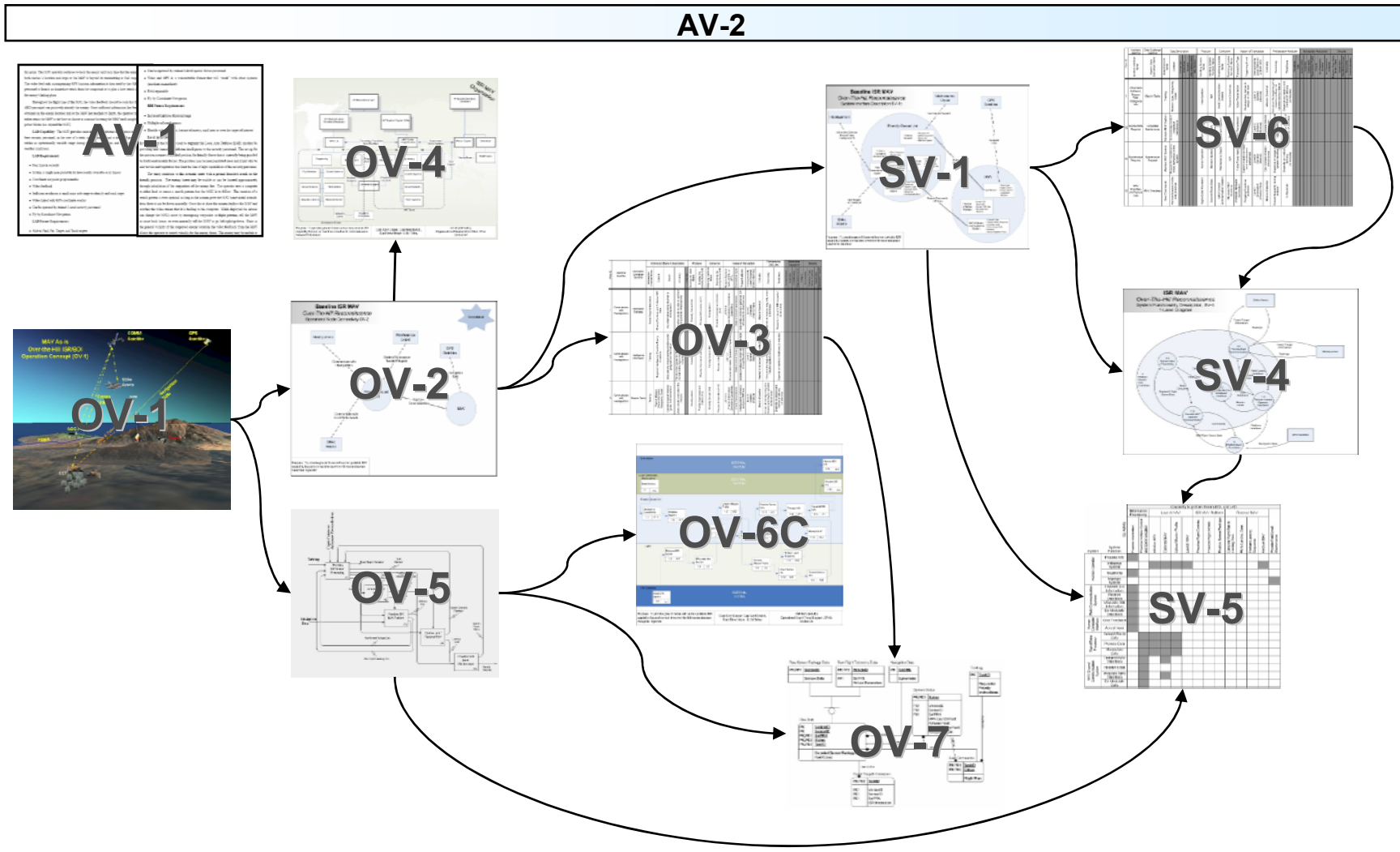
Methodology: Process



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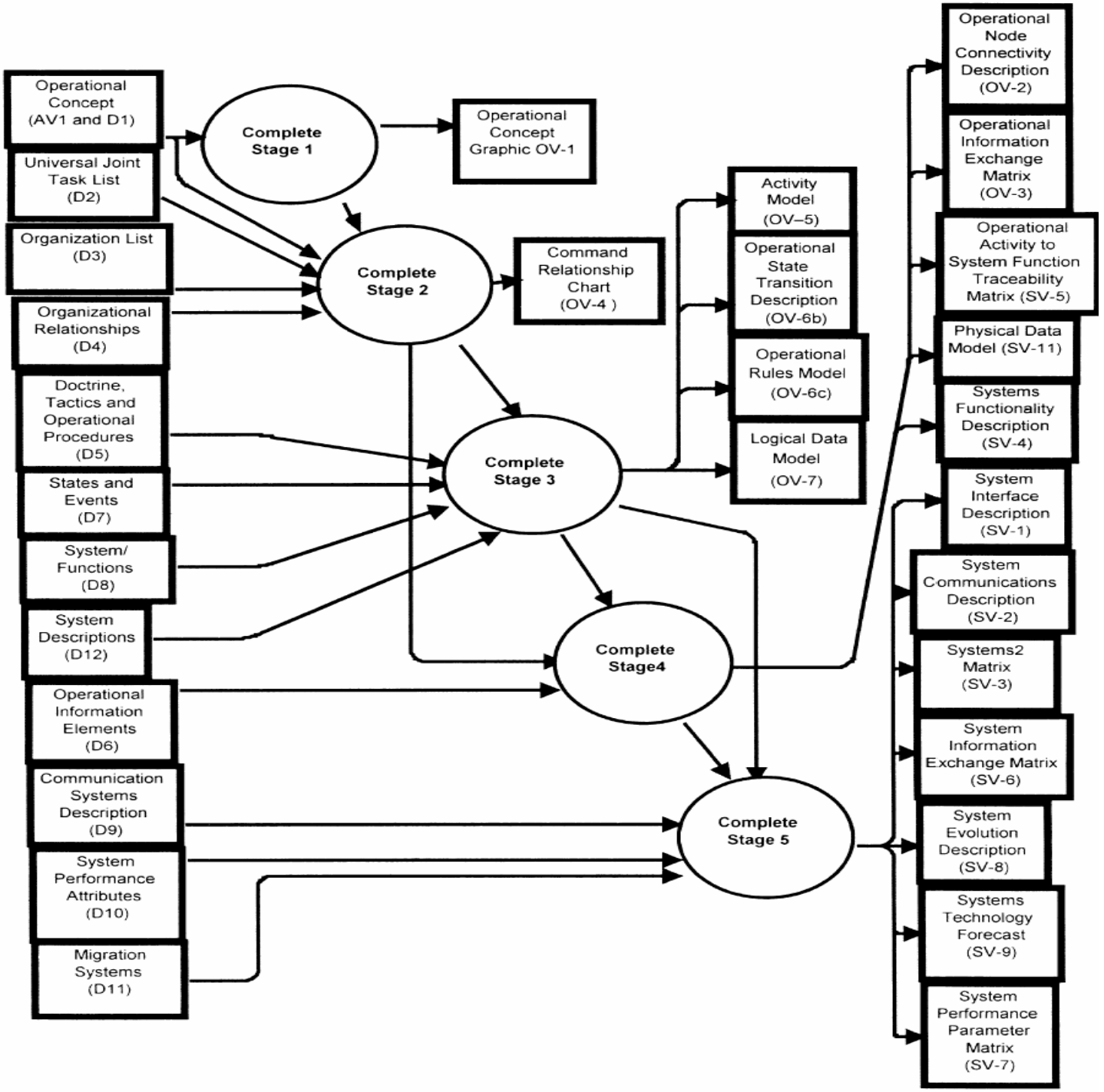
Dr. Levis' Architecture Product Process



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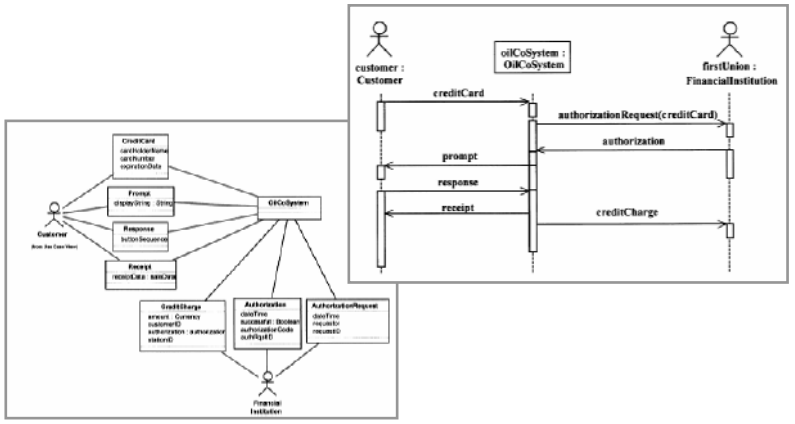
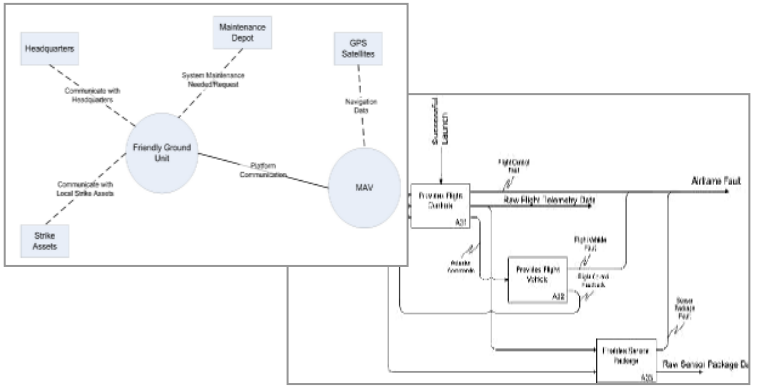
Methodology: Languages

- Unified Modeling Language (UML)
  - Object-Oriented (OO) approach
  - Based on data elements and their handling
  - Works well for software-based systems



- Integrated Computer Aided Manufacturing (ICAM) Definition (IDEF)
  - Structured Analysis (SA) approach
  - Based on functions and activities
  - Works well for physical systems



- This research uses IDEF languages through the SA approach.

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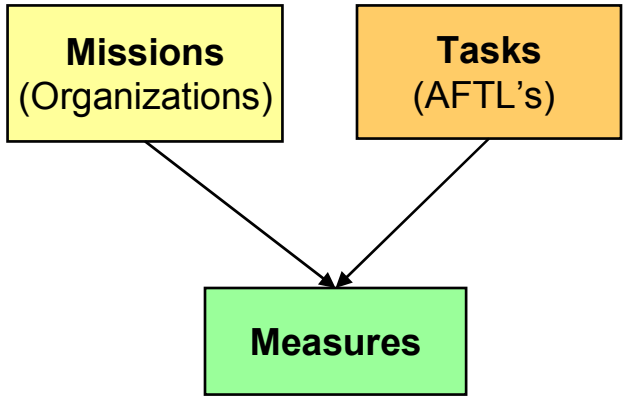
Methodology: Traceability

- **Traceability**
  - "The ability to describe and follow the life of a requirement, in both a forward and backward direction, i.e. from its origins, through its development and specification, to its subsequent deployment and use, and through periods of ongoing refinement and iteration in any of these phases." [Gotel]
  - All encompassing effort during architecture development
  - Requirement derivation from top-level national organizations and tasks



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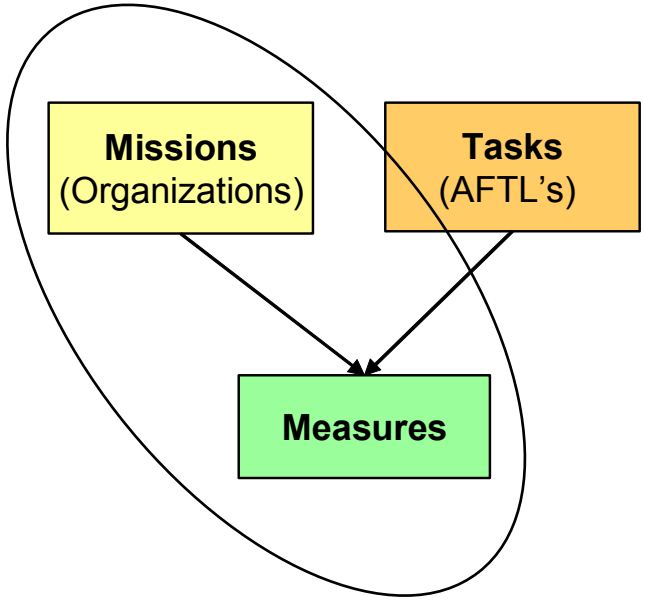
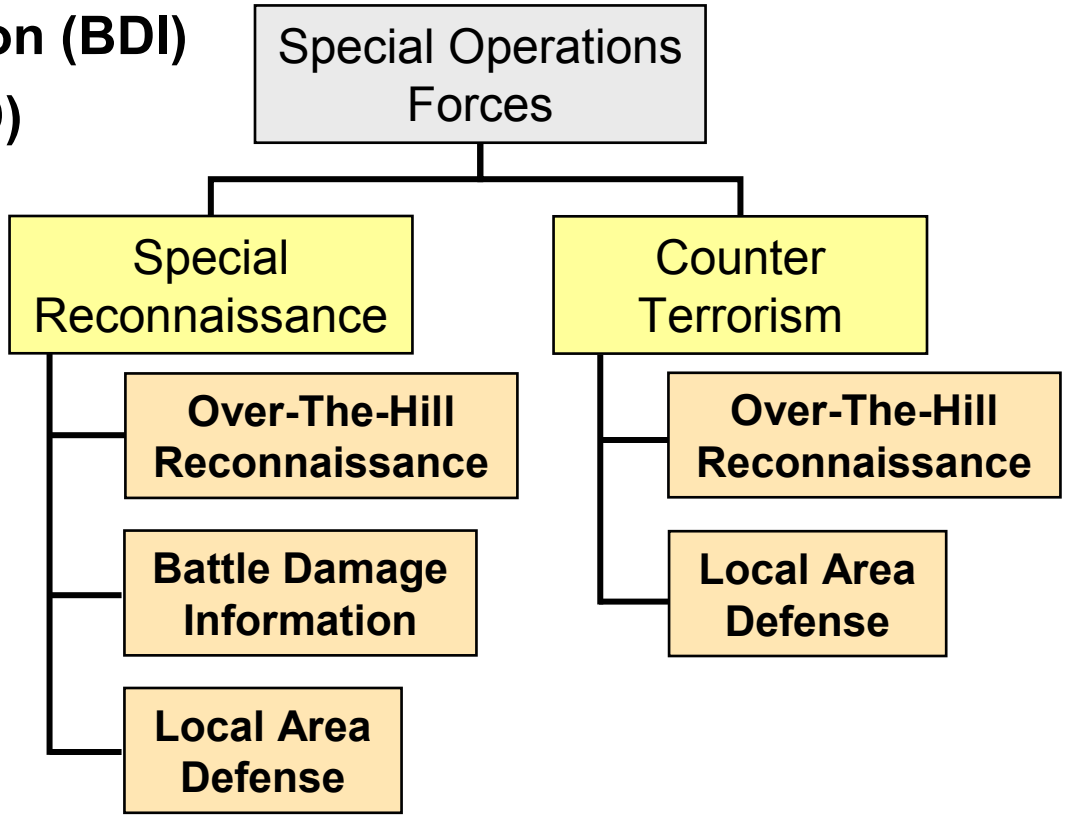
Results: Mission Traceability

- **Missions**
  - **Over-The-Hill Reconnaissance**
  - **Battle Damage Information (BDI)**
  - **Local Area Defense (LAD)**





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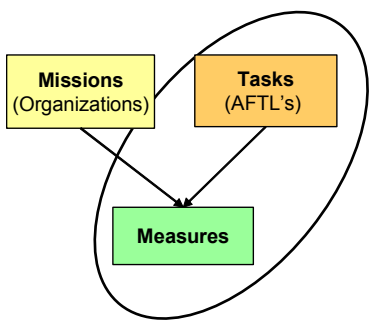
Results: Task Traceability



JOCs | JFCs | Task Analysis

AFTL ..... UJTL

- AFT 3 – Provide Information Superiority
  - AFT 3.1.1.1.1 – Perform Intelligence Activities
  - AFT 3.1.1.1.2 – Perform Surveillance
  - AFT 3.1.1.1.3 – Perform Reconnaissance
- AFT 6 – Provide Agile Combat Support
  - AFT 6.2.1.2 – Perform Force Protection

Over-the-hill Recon
- All tasks

Local Area Defense
- All tasks

Battle Damage Info
- AFT 3.1.1.1.1
- AFT 3.1.1.1.3

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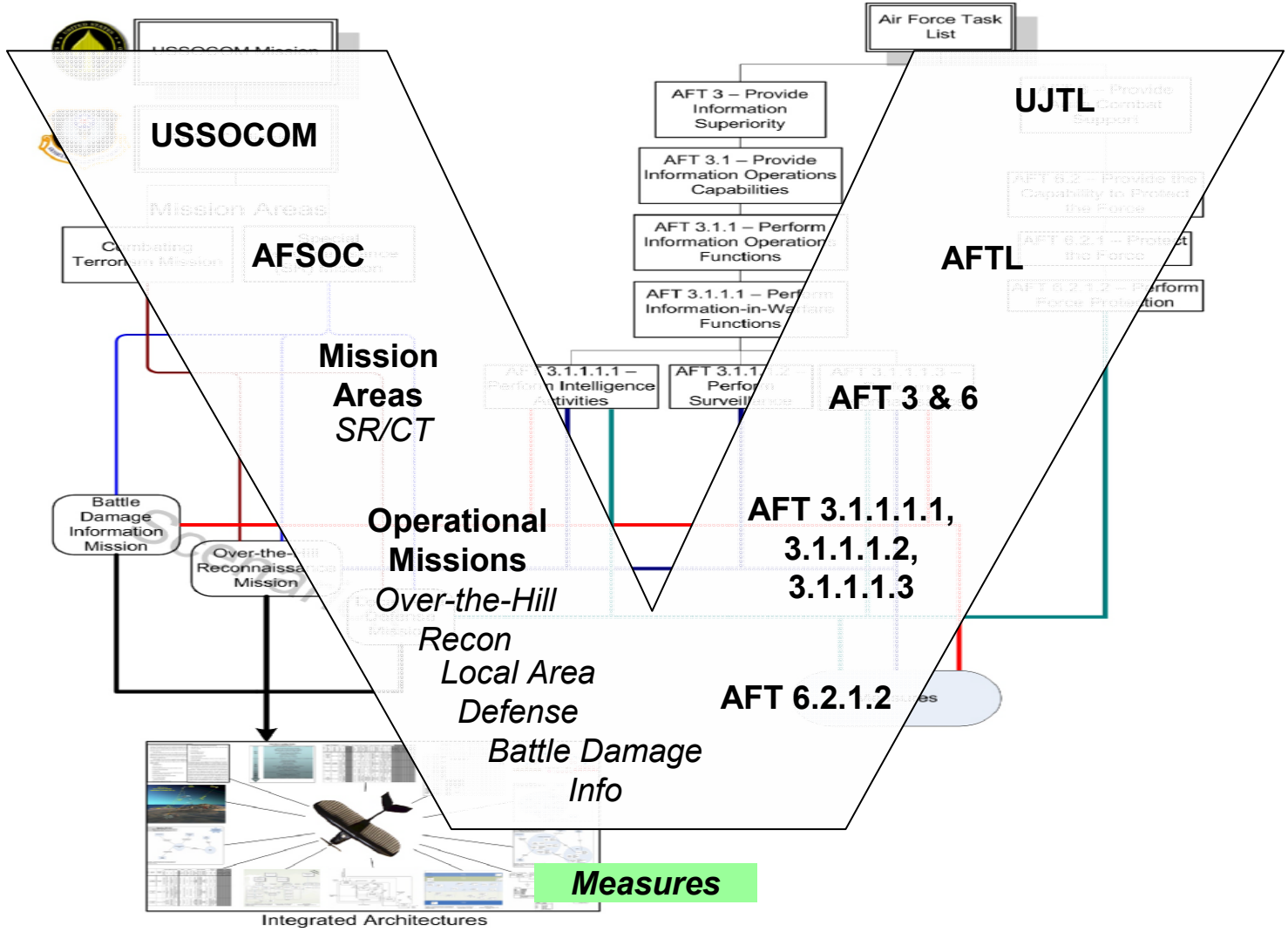
Results: Combined Traceability



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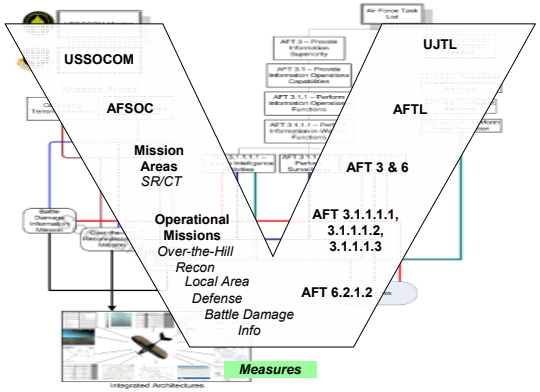
Results: Measures

Task	*Criterion*	*Measure*
AFT 3.1.1.1.1 Perform Intelligence Activities	Time	To conduct adequate, timely, and reliable intelligence activities for the USAF and other agencies.
	Percent	Of accuracy to which adversary COGs are identified to accomplish predetermined objectives.
	Cost	To Perform tactical intelligence activities.
AFT 3.1.1.1.2 Perform Surveillance	Time	To systematically observe air, or surface areas, places, persons, or things by visual, aural, electronic, photographic, or other means.
	Percent	Of accuracy to which air or surface areas, places, persons, or things can be observed by visual, aural, electronic, photographic, or other means.
	Cost	To perform surveillance.
AFT 3.1.1.1.3 Perform Reconnaissance	Time	To obtain, by visual observation or other detection methods, specific information about the activities and resources of an adversary or potential adversary.
	Percent	Of accuracy to which specific information about the activities and resources of an adversary or potential adversary is obtained.
	Cost	To perform reconnaissance.



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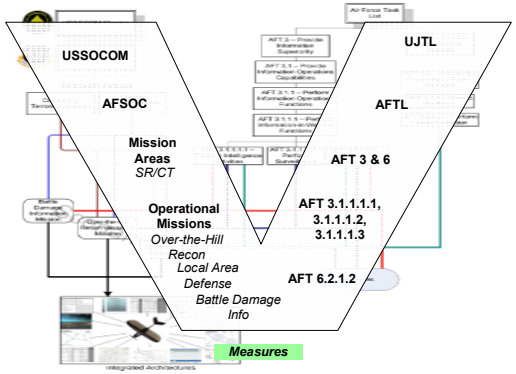
Results: Measures

Measures from Mission Scenarios and Architecture



- Percent of current field pack configuration
- Time to prepare the system for deployment
- Percent of coordinates properly programmed into the system
- Percent of video received by the user
- Percent of accuracy of visual interpretation
- Percent of accuracy of coordinates through user observation
- Percent of trained personnel fully capable of operating the system
- Percent of Nighttime Mission Effectiveness
- Degree to determine adequately repair needs and properly make the repairs
- Percent of loiter time that the intended coordinate is being observed
- Degree to which the system is capable of switching to/from automated/manual flight
- Time that the system can stay aloft
- Percent of locations that the system reaches

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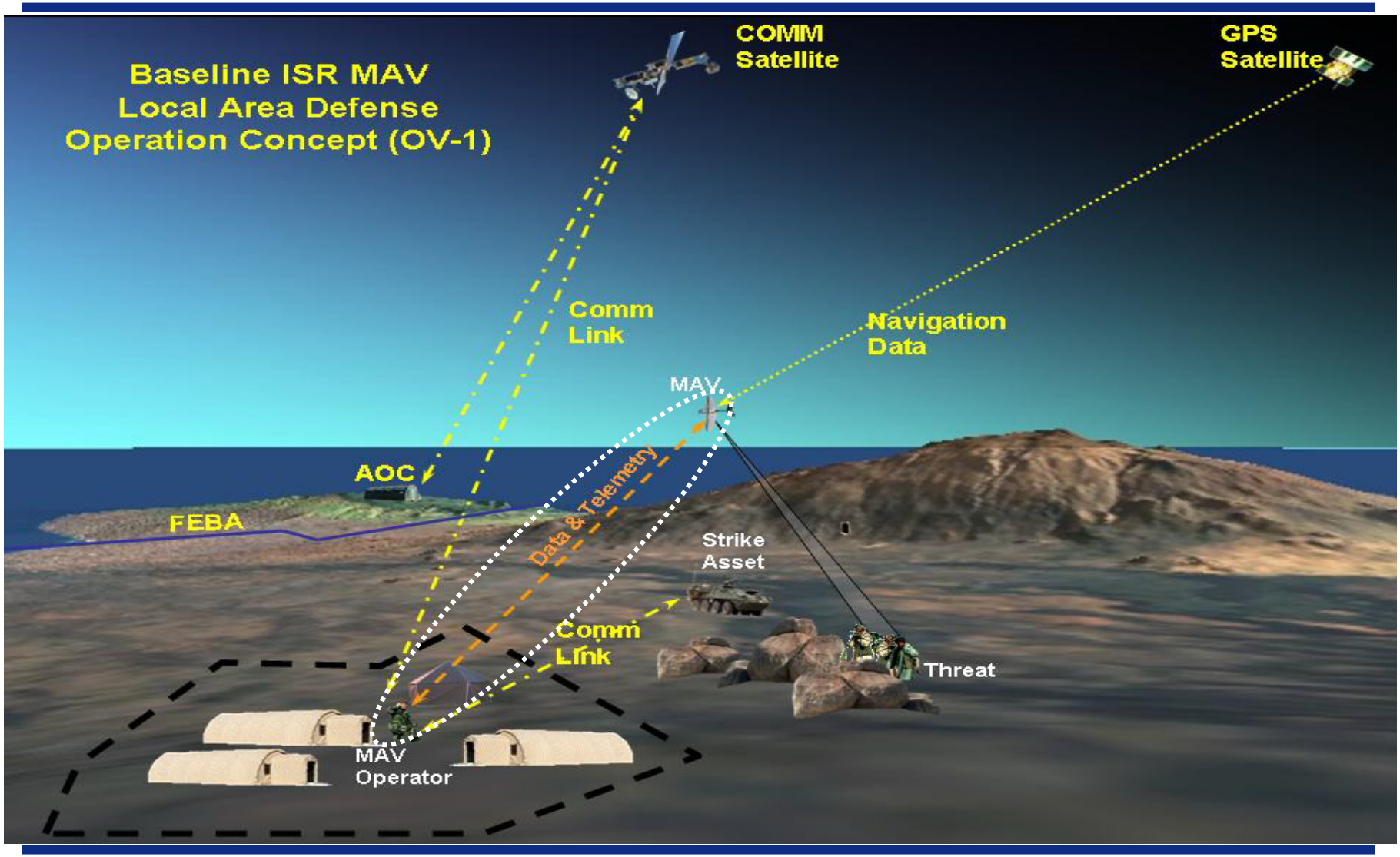
Results: OV Architectures



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Results: OV Architectures

Row ID	Needline Identifier	Information Exchange Identifier	Information Element Description					Producer		Consumer		Nature of Transaction					Performance Attributes		Information Assurance					Security			
			Information Element Name	Content	Scope	Accuracy	Language	Sending Op Node Name	Sending Op Activity Name & ID	Receiving Op Node Name	Receiving Op Activity Name & ID	Mission/Scenario UJTL, METL, or AFTL	Transaction Type	Triggering Event	Interoperability Level Required (from C4ISR WG)	Criticality	Periodicity	Timeliness	Access Control	Availability	Confidentiality	Dissemination Control	Integrity	Accountability	Protection (Type, Name, Duration)	Classification	Classification Caveat
1	Communicate with Headquarters	Information Gathered	Fused Target Information	Enemy Positions and Collected ISR Data	Any information being returned to Headquarters	Information should be able to get from the system to Headquarters		Friendly Ground Unit	Process Information (A11)	Headquarters	Provide Command and Control (A-2)	AFT 3.1 Provide Information Operations Capabilities	Data or Voice Transmission	User wishes to forward gathered ISR information to Headquarters	Level 1 Connected (Peer-to-Peer)	Mission Essential	Depends on mission, may only occur a few times	Depends on level of ISR requested (in minutes)									
2	Communicate with Headquarters	Intelligence Information	Tasking	Regional Intelligence, Possible Enemy Locations	Includes any known enemy positions and geographical information	Can be a best guess but the more accurate the Intel is the higher the chance of mission completeness		Headquarters	Provide Command and Control (A-2)	Friendly Ground Unit	Process Information (A11)	AFT 3.1 Provide Information Operations Capabilities	Data or Voice Transmission	Updated intelligence information is available through Headquarters	Level 0 Isolated (Manual)	Needed to increase Mission effectiveness	Occurs at the beginning of a mission and may be updated during mission	Depends on method of delivery (in minutes)									
3	Communicate with Headquarters	Mission Tasks	Tasking	Type of Mission (Recon/BDI/LAD), Waypoints, Goals	Contains type of mission, goals, and instructions	Users should understand the mission		Headquarters	Provide Command and Control (A-2)	Friendly Ground Unit	Process Information (A11)	AFT 3.1 Provide Information Operations Capabilities	Voice Transmission	Headquarters wishes to assign an ISR task	Level 0 Isolated (Manual)	Mission Essential	Occurs at the beginning of a mission and may be updated during mission	Depends on mission and method of delivery (in minutes)									

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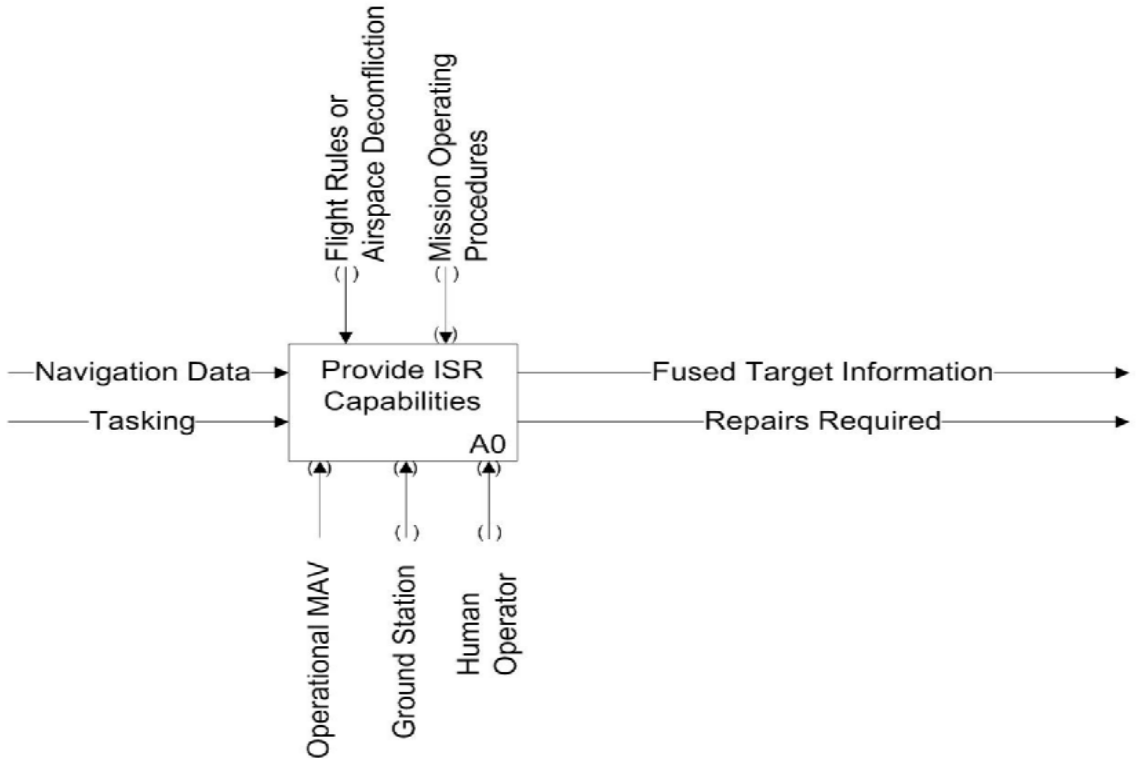
Results: OV Architectures

Baseline ISR MAV

Operational Activity Model OV-5

Context Diagram A-0



Purpose: To provide ground forces with a single-man packable, single-man operable ISR capability.
Viewpoint: Operator

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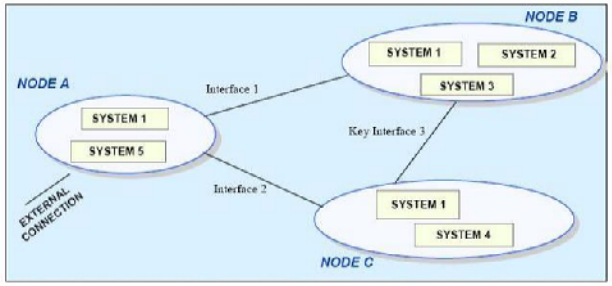
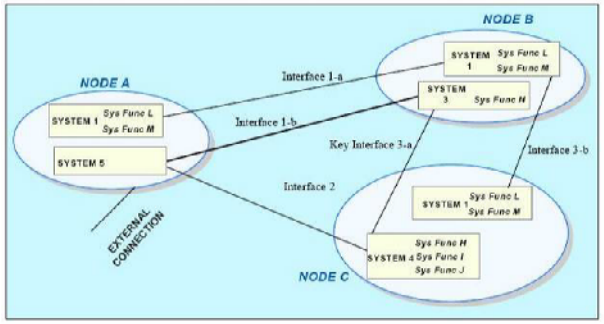
Results: SV Architectures

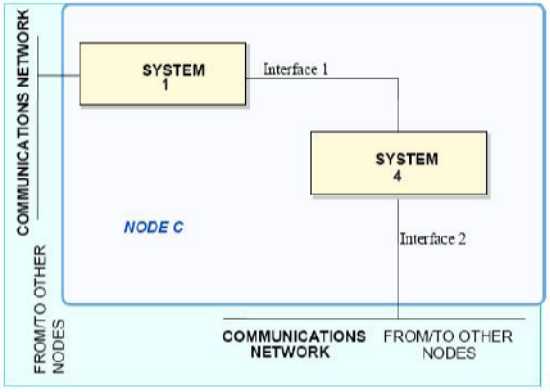
SV-1: System Interface Description



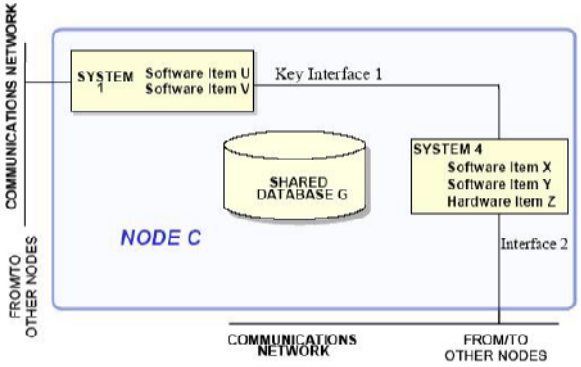
SV-1a: Internodal showing node-to-node interfaces



SV-1b: Internodal showing system-to-system interfaces



SV-1c: Intranodal showing interfaces within each node

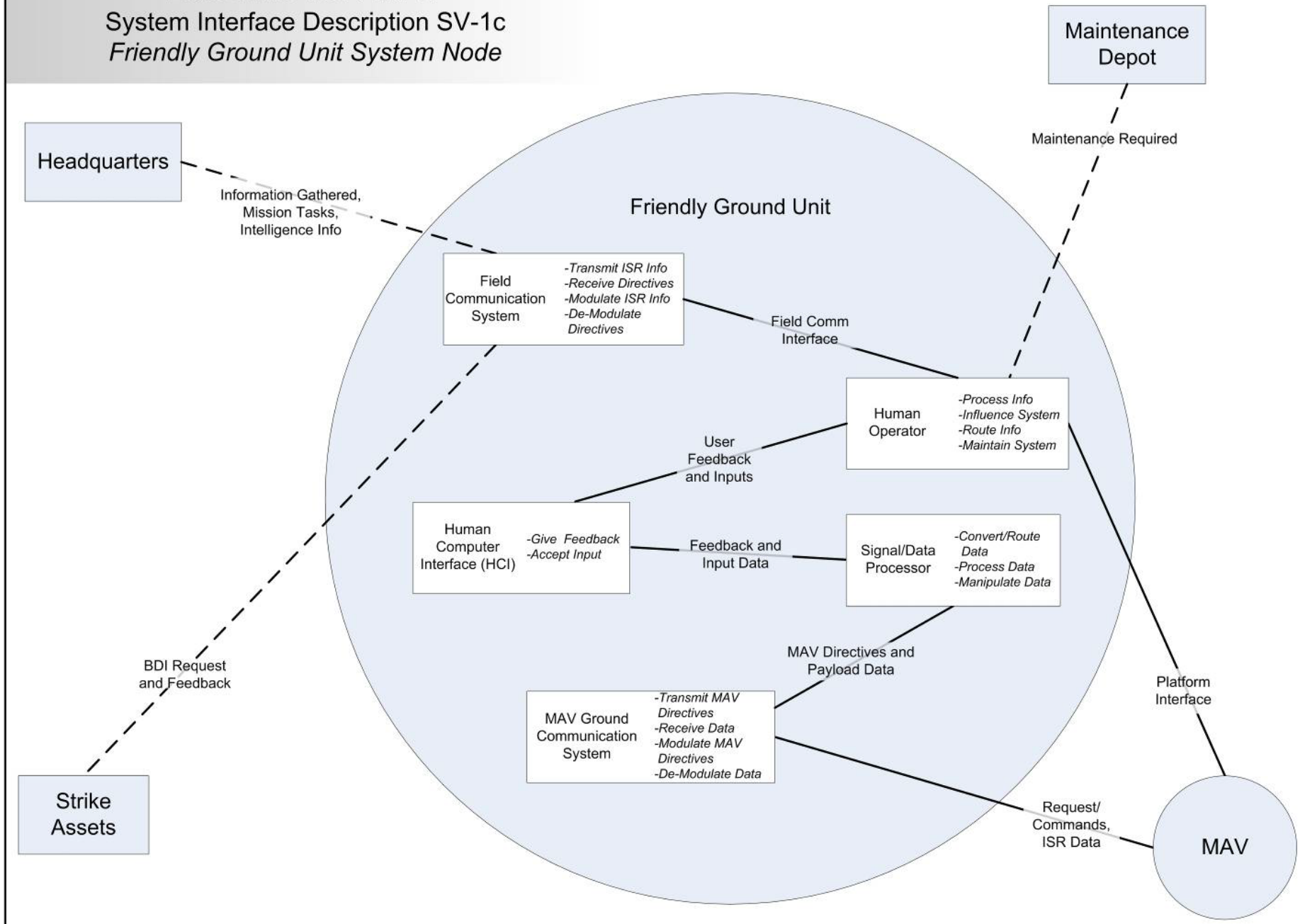


SV-1d: Intrasystem showing hard/software items

Baseline ISR MAV

System Interface Description SV-1c

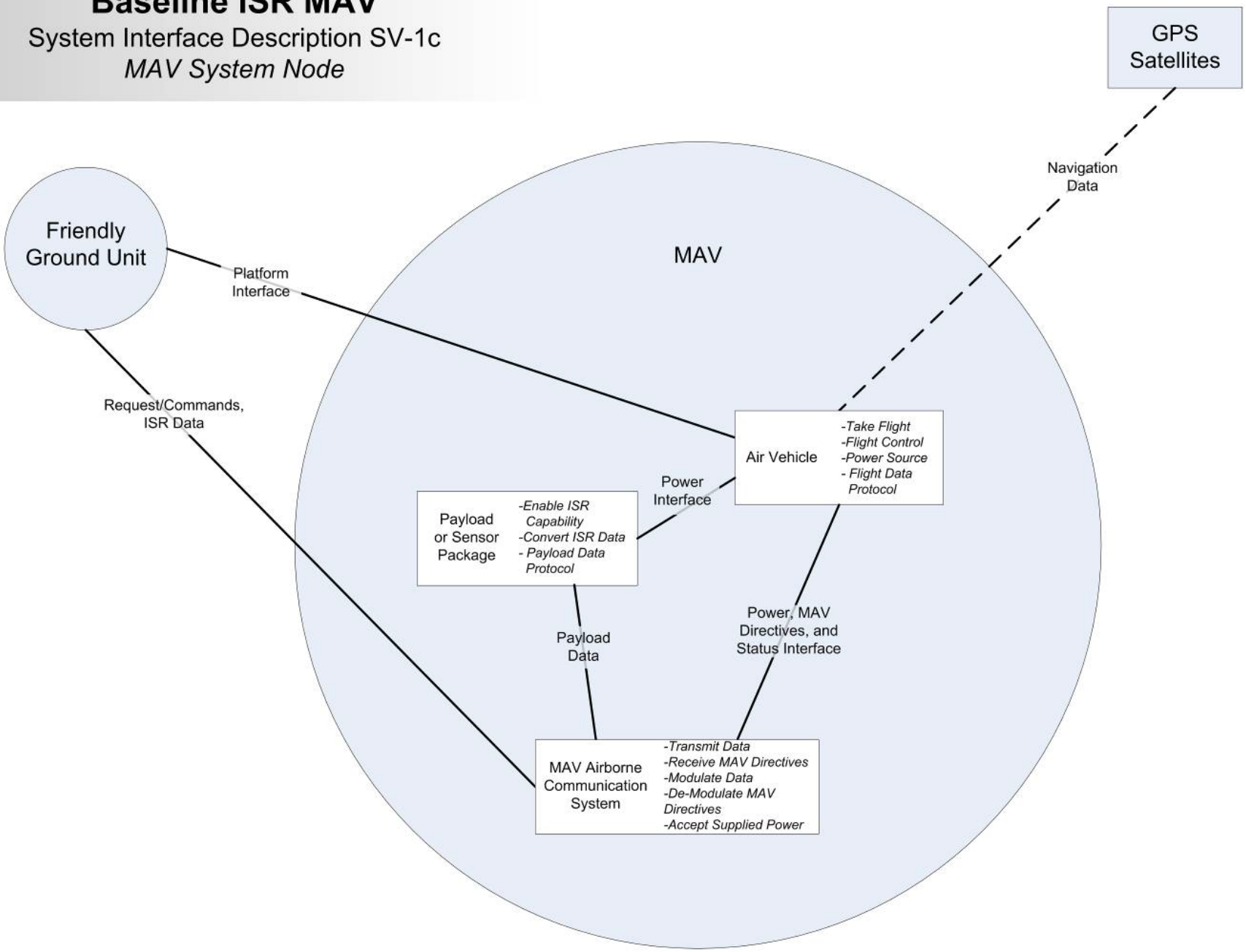
Friendly Ground Unit System Node



Baseline ISR MAV

System Interface Description SV-1c

MAV System Node



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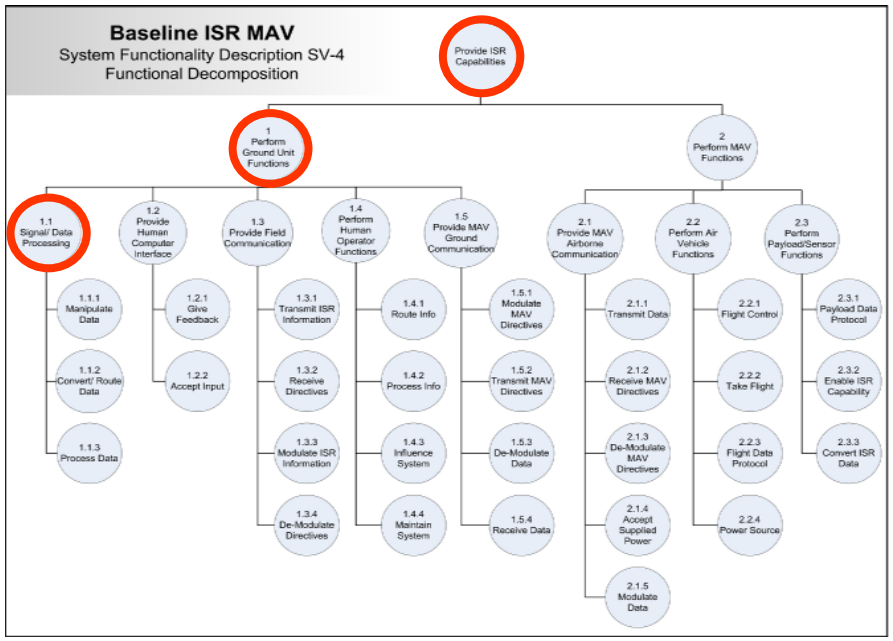
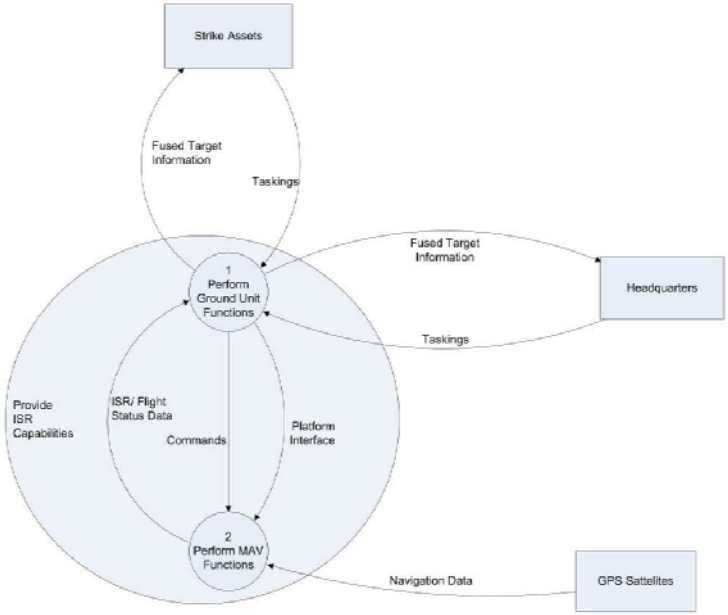
Results: SV Architectures

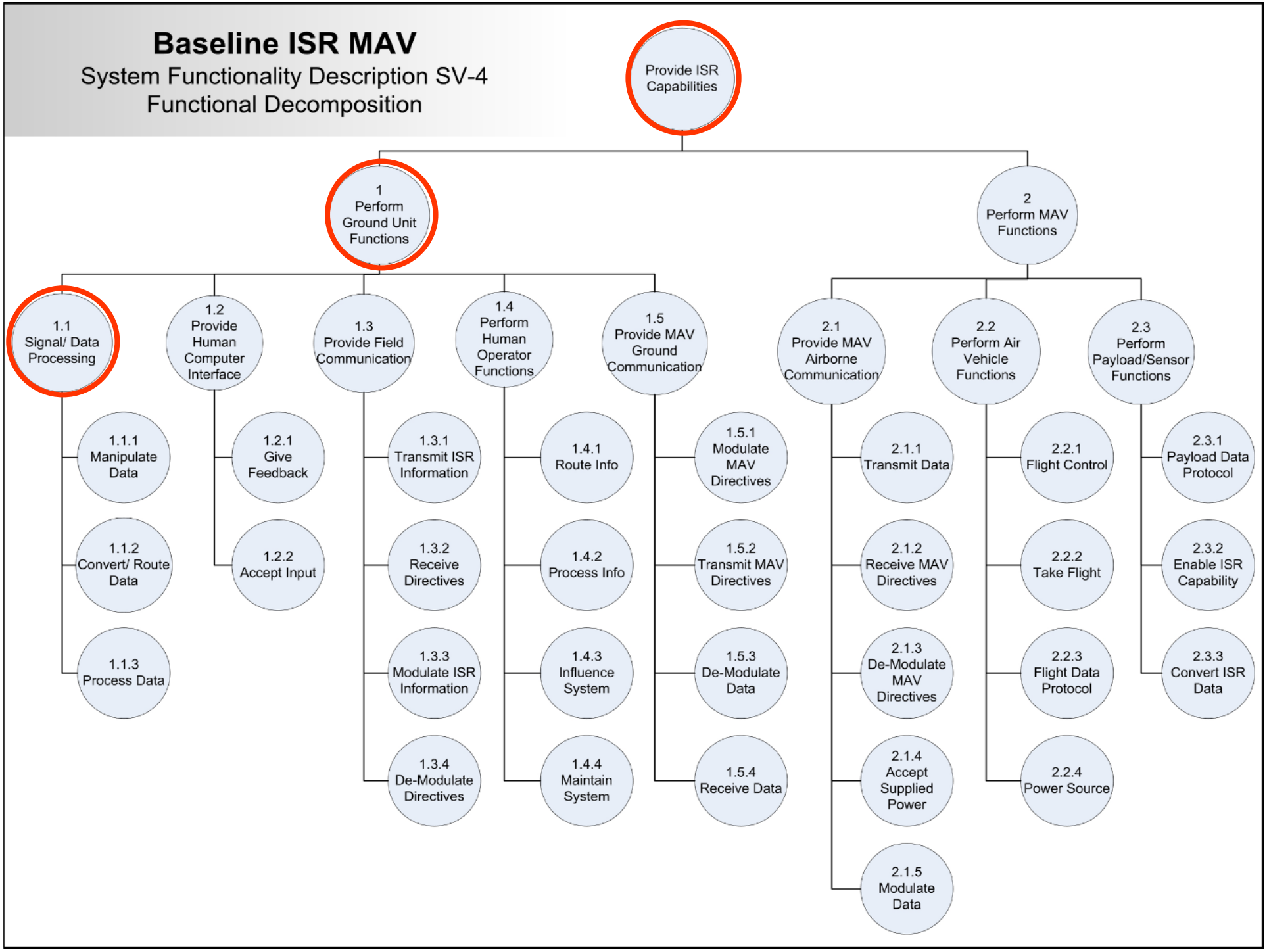
- **SV-4: Systems Functionality Description**
  - **Documents system functional hierarchies and system functions, and the data flows between them**





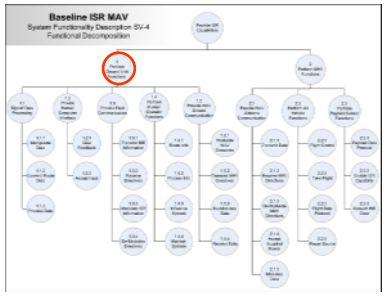
Baseline ISR MAV

System Functionality Description SV-4
Functional Decomposition



Baseline ISR MAV

System Functionality Description SV-4
1-Level Diagram



Strike Assets

Fused Target Information

Taskings

1.3 Provide Field Communication

Fused Target Information

Headquarters

Taskings

1.1 Signal/ Data Processing

Output Data

Input Data

Field Comm Interface

Field Comm Interface

1 Perform Ground Unit Functions

MAV Directives

1.2 Provide Human Computer Interface

User Feedback

1.4 Perform Human Operator Functions

Payload / Flight Status Data

Human Inputs

1.5 Provide MAV Ground Communication

Commands

Platform Interface

GPS Sattelites

ISR/ Flight Status Data

2 Perform MAV Functions

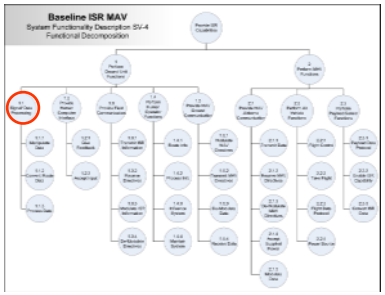
Navigation Data

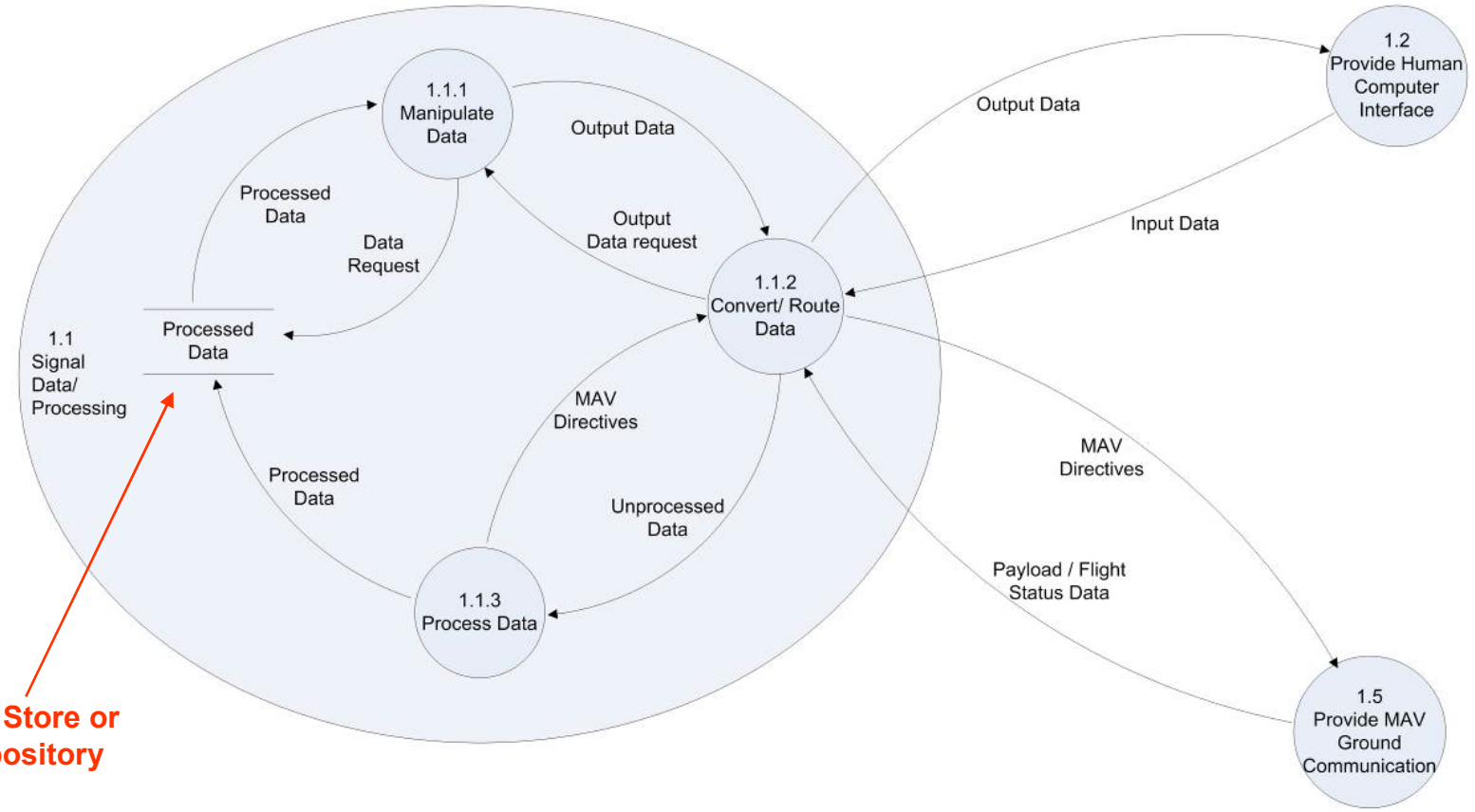
Same Level Function

Baseline ISR MAV

System Functionality Description SV-4

1.1-Level Diagram





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Results: SV Architectures

Row ID	Interface Identifier	Data Exchange Identifier	Data Description						Producer		Consumer		Nature of Transaction				Performance Attributes		Information Assurance							Security				
	System Interface Name	System Data Exchange Name	Data Element Name	Content	Format Type	Media Type	Accuracy	Units of Measurement	Sending System Name	Sending System Function Name	Receiving System Name	Receiving System Function Name	Transaction Type	Triggering Event	Interoperability Level Achieved (C4ISR WG)	Criticality	Periodicity	Timeliness	Throughput	Size	Access Control	Availability	Confidentiality	Dissemination Control	Integrity	Non-Repudiation Producer	Non-Repudiation Consumer	Protection (Type, Name, Duration, Date)	Classification	Classification Caveat	Releasability	Security Standard
1	BDI Request and Feedback	BDI Feedback	Fused Target Information	BDI Confirmation and general ISR information gathered					Field Communication System	Transmit ISR Info	Strike Assets	N/A	Voice Transmission	User needs to communicate to Strike Assets	Level 0 Isolated (Manual)	Can increase mission effectiveness	Does not occur often however it depends on the battlefield situation	Depends on method of delivery (in minutes)														
2	BDI Request and Feedback	BDI Request	Tasking	BDI Type, Enemy Positions, Status/Type of Strike					Strike Assets	N/A	Field Communication System	Receive Directives	Voice Transmission	Strike Asset cannot perform BDI therefore request a BDI mission	Level 0 Isolated (Manual)	Mission Essential	Does not occur often however it depends on the battlefield situation	Depends on method of delivery (in minutes)														
3	Feedback and Input Data	Feedback Signal	Decoded Sensor Package Data	Audio and Video Signals					Signal/Data Processor	Convert/Route Data	Human Computer Interface	Give Feedback	Internode Hardware Connection	Processor Sends Feedback Signal	Level 1 Connected (Peer-to-Peer)	Mission Essential	Feedback constantly being supplied	Feedback in seconds														
4	Feedback and Input Data	Input Data	Flight Plan	Keyboard, Mouse, Touch Screen Signals					Human Computer Interface	Accept Input	Signal/Data Processor	Process Data	Internode Hardware Connection	HCI detects input	Level 1 Connected (Peer-to-Peer)	Mission Essential	Varies by user and mission (at least twice)	Input in seconds														

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Results: DOTMLPF

- **DOTMLPF Considerations**
  - **JCIDS places emphasis on addressing a capabilities' impact in the areas of DOTMLPF**
  - **Doctrine**
    Real-Time Situational Awareness will influence mission decisions and possibly increase force employment to areas of unknown conditions.
  - **Organization**
    Changes can occur in the tactical realm and developmental/sustainment realm

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Results: DOTMLPF

- **DOTMLPF Considerations**
  - **Training**
    Original requirement of 'operable by trained personnel' remains. Types of training can include classroom, field, virtual, verbal, written, on-the-job-training, etc.
  - **Material**
    The ISR MAV architected serves as a material solution to the capability gap identified

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Results: DOTMLPF

- **DOTMLPF Considerations**
  - **Leadership and Education**
    - ***Increased local area situational awareness can impact leaders decisions in the field***
    - ***The units education would need to include this new tactical capability.***
  - **Personnel**
    - ***Impacts depend on manner in which the ISR MAV is employed***
    - ***Tactical Specialty Codes could emerge***

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Results: DOTMLPF

- **DOTMLPF Considerations**
  - **Facilities**
    - ***Should be minimal***
    - ***Largely dependant on how their development, sustainment and logistics are managed***

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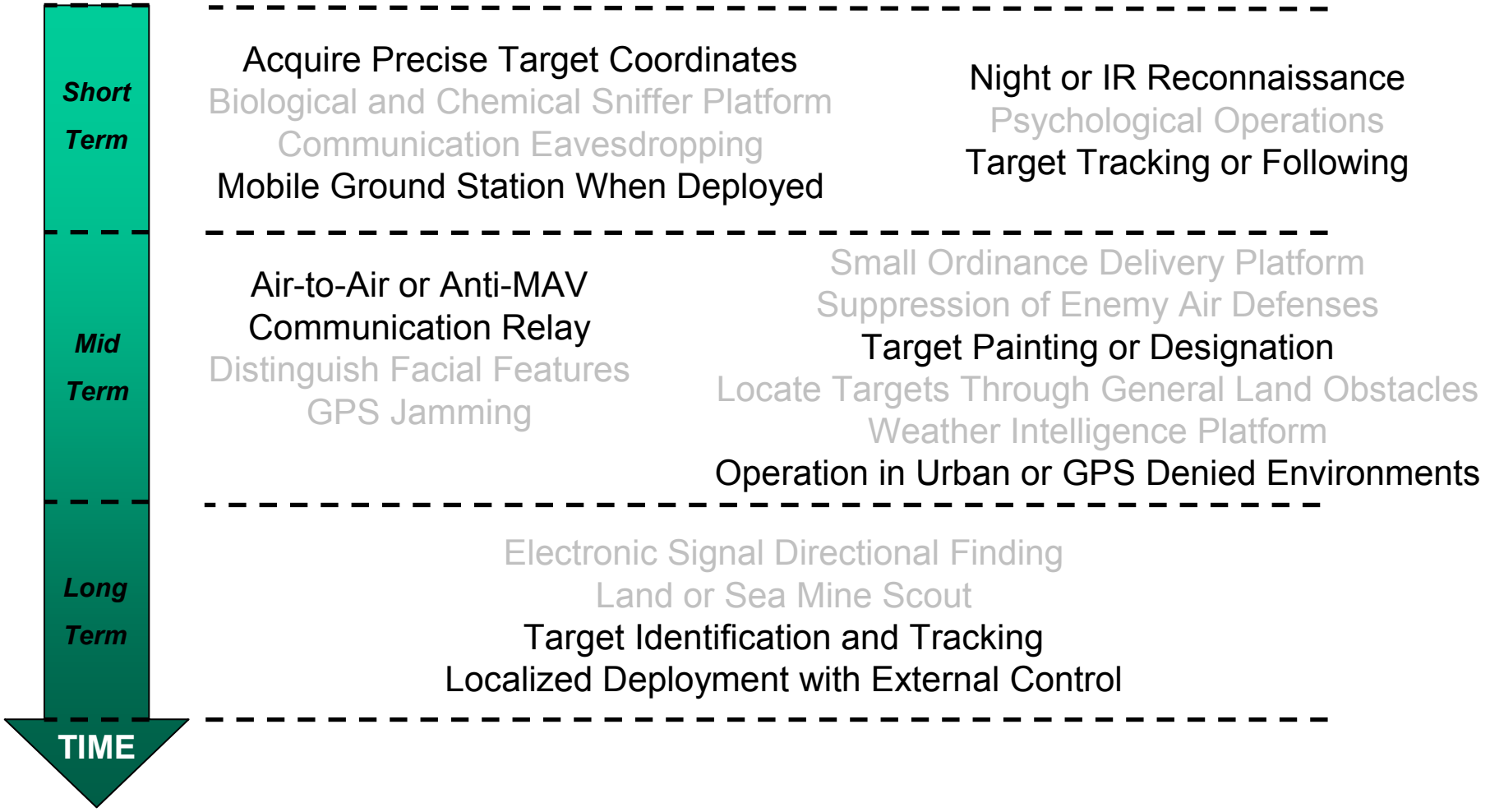
Results: Future Capabilities

Future Capability Timeline:



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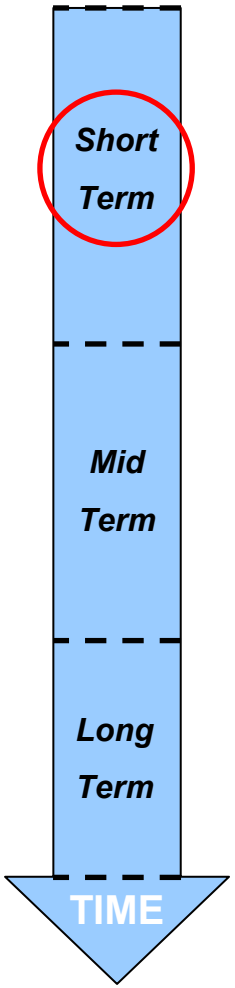
Future Capabilities



- **Capability -** Acquire Precise Target Coordinates
- Enabling Technologies
  - Improved Precision Of MAV GPS Sensor
  - Range Finder For Use With EO Or IR Sensors
  - Possible Height Above Ground Sensor or DTED
- Architecture Impacts
  - Range/Height can morph into the “Raw Sensor Package Data” link to the ground station
  - Minimal Changes To OV and SV Products
  - New Hardware Impacts System Design
    - Ensure Tx/Rx Can Process The Data
    - Target Coordinates Calculated by Ground Station

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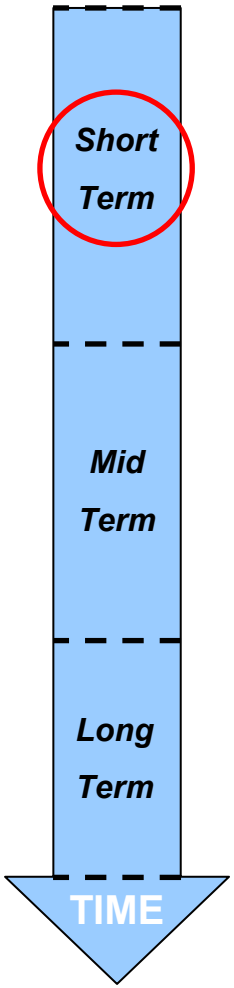
Future Capabilities



- **Capability –** Mobile Ground Station When MAV Deployed
- Enabling Technologies
  - Geolocation Capability For The Ground Station
  - Improved Human Interface Enabling Mobility
- Architecture Impacts
  - Minimal Changes To OV Or SV Products As Information Flows To And From The Ground Station Are The Same
  - New Hardware Impacts System Design And Ground Station Requirements

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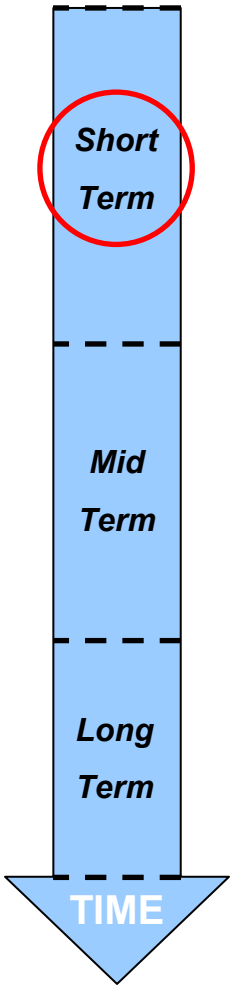
Future Capabilities



- **Capability –** Night Or IR Reconnaissance
- Enabling Technologies
  - Modular Payload Bay In MAV
  - Miniaturized Night Or IR Sensor
  - Possible Sensor Fusion
- Architecture Impacts
  - Minimal Changes To OV Or SV Products If Only One Camera Is Used At A Time
  - New Hardware Impacts System Design And Modular Payload Bay Impacts MAV And Payload Requirements

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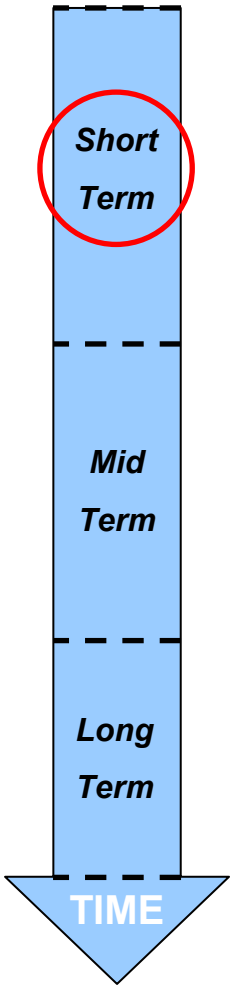
Future Capabilities



- **Capability –** Target Tracking Or Following
- Enabling Technologies
  - Image Recognition Hardware/Software In MAV Or High Data Rate Communication If Processing In Ground Station
  - Improved Loiter Time Via Fuselage Improvements Or Improved/Better Power Source
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities
  - Changes To SV Products Since The Target Dictates The Flight Plan Not Just The GPS Waypoints
  - New Hardware Impacts System Design

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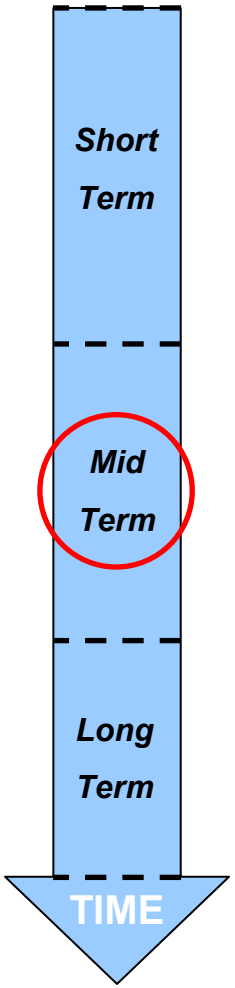
Future Capabilities



- **Capability –** Air-to-Air or Anti-MAV/UAV
- Enabling Technologies
  - Miniaturized Friend or Foe Sensor
  - Onboard sensors to locate enemy MAVs
  - Development of Anti-MAV tactics/doctrine
  - Offensive Anti-MAV capability via MAV or ground unit
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities
  - Changes To SV Products Due To New Intranodal Communication and Interfaces
  - System Design Impacted By New Hardware For MAV And Software Changes To Ground Station

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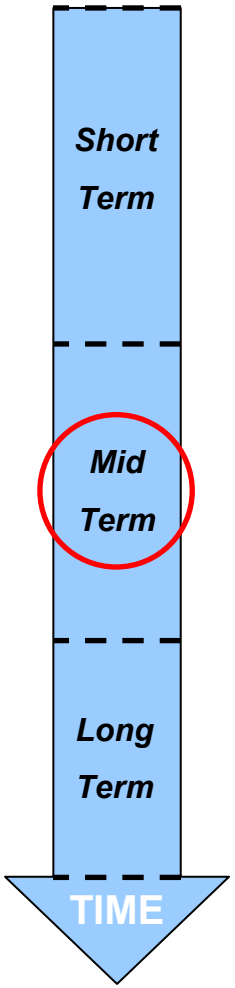
Future Capabilities



- **Capability –** Communication Relay
- Enabling Technologies
  - Miniaturizing A Ground Station Receiver Into The MAV
  - Improved Loiter Time Via Fuselage Improvements Or Improved/Better Power Source
  - Ability To Send Either Raw Or Processed Sensor Data To External Users
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities And A New Communication Node
  - Changes To SV Products Due To New Intranodal Communication And Interfaces
  - System Design Impacted By New Hardware For MAV And Software Changes To Ground Station

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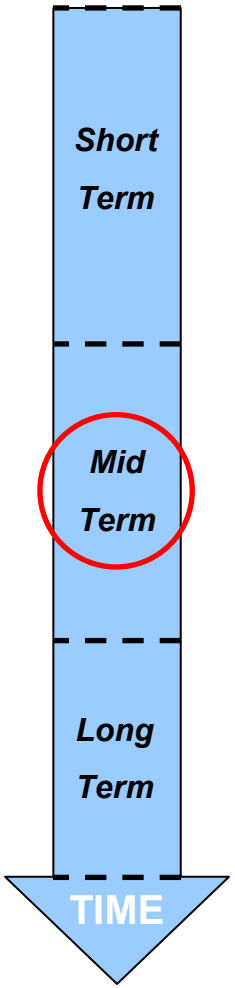
Future Capabilities



- **Capability –** Operation In Urban Or GPS Denied Environments
- Enabling Technologies
  - Non Line-of-sight Communications
  - Autonomous Navigation Aided By DTED, Collision Avoidance Sensors, Environment Map, Etc.
  - Communication Relay To Other MAVs
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities
  - Changes To SV Products Due To New Intranodal Communication And Interfaces
  - System Design Impacted By New Hardware For MAV And Software Changes To Ground Station

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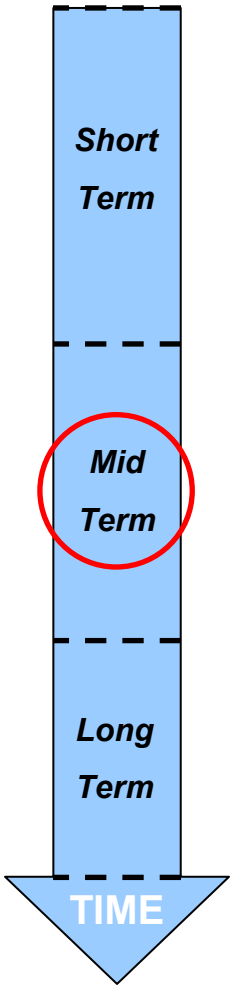
Future Capabilities



- **Capability –** Target Painting or Designation
- Enabling Technologies
  - Acquire Precise Target Coordinates
  - Target Tracking or Following
  - Sufficiently Powered Laser for the MAV
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities
  - Changes To SV Products Due To New Intranodal Communication and Interfaces
  - System Design Impacted By New Hardware For MAV And Software Changes To Ground Station

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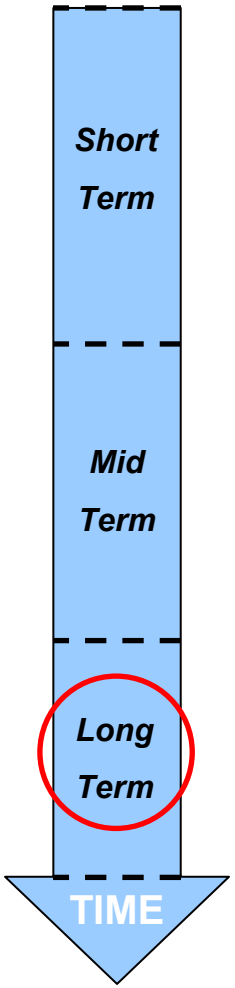
Future Capabilities



- **Capability –** Target Identification And Tracking
- Enabling Technologies
  - Target Tracking Or Following
  - Either Onboard Or Ground Station Based Identification
  - Increased Resolution Cameras
- Architecture Impacts
  - Changes To OV Products Due To New Operational Activities
  - Changes To SV Products Due To New Intranodal Communication And Interfaces
  - System Design Impacted By New Hardware For MAV And Software Changes To Ground Station

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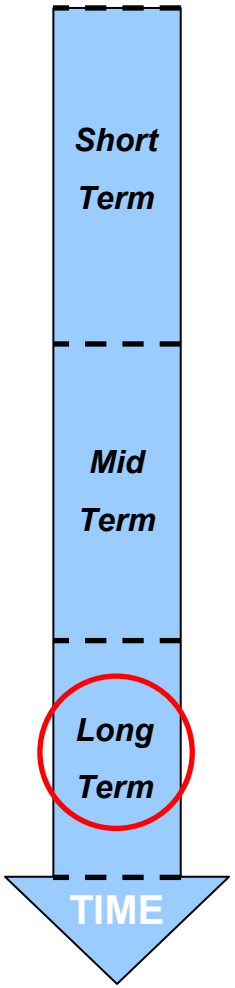
Future Capabilities



- **Capability –** Localized Deployment with External Control
- Enabling Technologies
  - Network-centric control structure
  - Ability to transmit sensor data and receive control direction beyond current system boundary
- Architecture Impacts
  - All Products Require Changes Due to New Nodes, Communication Lines and Functions
  - System Design Impacted By New Hardware For MAV And Hardware/Software Changes To Ground Station

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Results: Future Techs

Future MAV Technology Capabilities

- Enhanced Optical Sensor Capabilities
- GPS Integration into Ground Station
- Integrated Ground Station
- Low Light Emitting Display
- Low Probability of Intercept Communications
- Modular and Swappable Payloads
- Multiple Sensor Payload
- Non-Line-Of-Sight Communications
- Reduce DTED Level 2 in Real-Time
- Sensor and/or Image Stabilization

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Results: Future Techs

- **Other Future MAV Technology Capabilities**
  - Common Power supply system for all ground based systems
  - Communications Intelligence (COMINT) sensors
  - Daylight Imaging System (DIS)
  - Diesel Powerplant
  - Enhanced Aerodynamics for increased lift and power efficiency
  - Enhanced Battery Power
  - Enhanced Field of View optical sensors or sensor array
  - Fuel Cells
  - Forward looking infrared (FLIR)
  - HF/VHF/UHF Directional Finding Equipment
  - Increased Data Processing Onboard Air Platform (lightweight, low power)
  - Infrared line scanner (IRLS)
  - Reduce DTED Level 5 data in near real time
  - SATCOM
  - Small, Low Power Lasers (for range finding, target designation)
  - Small, Low Power Optical Sensors for Night Vision
  - Solar Power (alternate fuel or in flight recharge)
  - Synthetic Aperture Radar (SAR)

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Conclusion: FAS

- Swarming MAV Detailed Architectures
- DoD Integration Of MAV Use
- MAV Observation/Targeting Stabilization Study And Analysis
- Fully Develop Future Architectures

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Conclusion: Recommendations

- Recommendations
  - Accept And Update This As The Baseline ISR MAV Architecture
  - Expand This Architecture Into The Dynamic Realm To Look At Performance Comparisons Of Proposed Systems