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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

AN INSTRUCTIONAL DESIGN REFERENCE MISSION FOR SEARCH AND RESCUE OPERATIONS

by

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14. ABSTRACT

The objective of this instructional guide is to help learners gain practice with the proper framing of a problem for analysis, the first and most critical step in systems architecture and design. A Design Reference Mission (DRM) is outlined and populated with example content for a notional Search and Rescue (SAR) mission. The DRM establishes an operational context, description(s) of the environment and situations in which a system of interest is expected to operate, an operational narrative containing enough detail to generate multiple operational scenario variants, a sequence of operational activities and interactions between each system and other systems in its environment, and measures for establishing goals for mission success. The DRM is to be used to derive specific scenarios for use in making design decisions concerning candidate operational and solution architectures aimed at satisfying the mission success requirements.

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I. INTRODUCTION

"The righter you do the wrong thing, the wronger you get."

- Russell Ackoff

The objective of this instructional guide is to help learners gain practice with the proper framing of a problem for analysis, the first and most critical step in systems architecture and design. The pressures of reality to arrive at a solution quickly often make it challenging to spend adequate time making sure the problem is understood, but failure to do so can result in a solution to the wrong problem. A well-functioning team takes time at the very beginning of any effort to organize the initially provided source material into a properly framed problem to be solved, before proceeding into months' or even years' worth of work down a potentially wrong path.

The conceptual framework for understanding systems depicts that a system is developed to fulfill a mission, **Figure 1** (IEEE 2000).

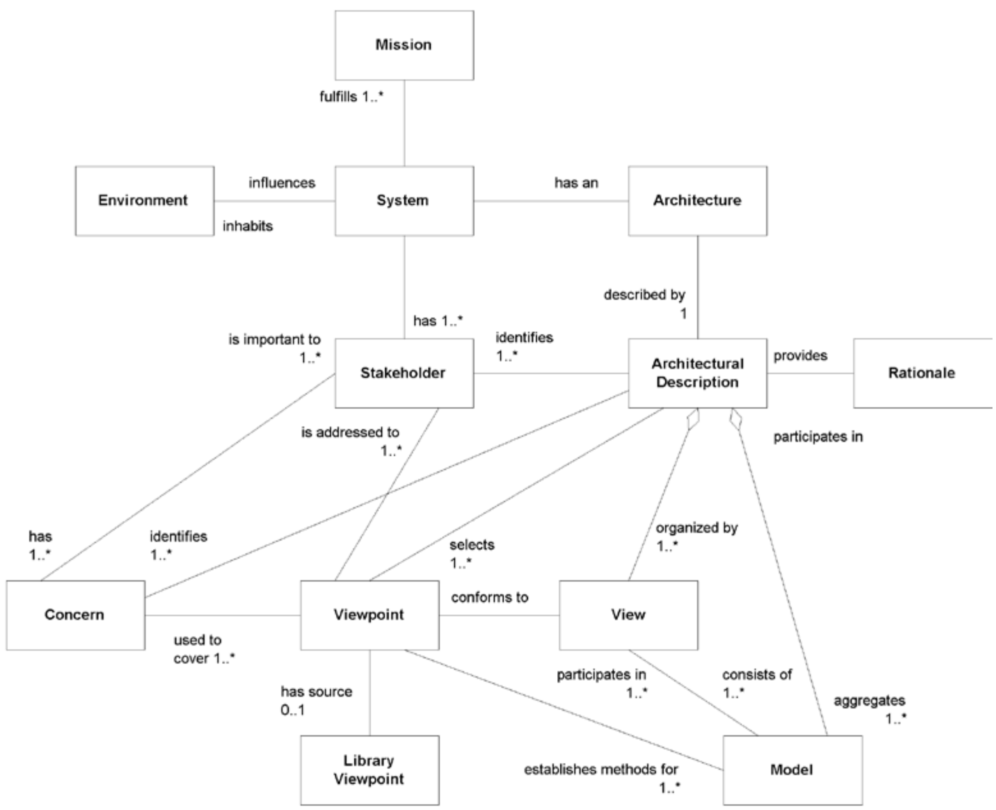

Figure 1. Conceptual Framework for Systems (from IEEE 2000).

The process of systems engineering starts with the Business or Mission Analysis Process (INCOSE 2015). It is the context of the mission of the system, and the related enterprise, that systems development begins by defining the problem or opportunity. For typical non-defense systems, terms such as concept of operations (ConOps) and operations concept (OpsCon) are used to describe the system usage. A ConOps defines how one or more systems forwards an organization's objectives from an enterprise perspective (INCOSE 2015). An OpsCon defines how the system works from the end user perspective (INCOSE 2015). For defense systems, where the word "mission" refers to the operational sequence of events to accomplish military tasks, the use of a mission context provides a useful way to assess the effectiveness of a system in familiar terms, instead of using an OpsCon. The Design Reference Mission (DRM) construct provides a well-defined method to accomplish this.

This guide outlines a DRM for a notional Search and Rescue (SAR) operation to illustrate this method for capturing a problem description for use in subsequent analyses. The remaining sections of Chapters I, II, and III constitute an instructional outline containing example content for a DRM. For more background about design reference missions, see (Skolnick 2000).

A. DRM OBJECTIVE

This DRM outlines an operational context for a SAR mission, from which specific SAR scenarios may be derived for use in making design decisions concerning candidate operational and solution architectures aimed at satisfying mission success requirements. The analysis question motivating the development of this DRM is the following: *How could robotic / unmanned system(s) be employed to increase SAR mission success, while maintaining or reducing lifecycle costs, as compared with an architecture that does not utilize robotic / unmanned systems?* This DRM contains several examples of many possible SAR mission variants to serve as a context for the follow on analysis of generating numerous SAR use cases to support answers to such analysis questions.

B. MISSION BACKGROUND

The conduct of SAR operations can be dated back to 1655, with attempts by the Dutch to recover the crew and contents of the wrecked ship *De Vergulde Draeck* off the coast of Australia. From logbook entries, early SAR appeared to consist simply of sending numerous surface assets to the last known location of the asset to be recovered, and searching the coastline for signs of wreckage (Major 1859, 77). The limited success of these practices did not stymie hope of rescue and recovery, despite the risk to the SAR personnel and assets. This mindset has persisted through the years of humans efforts to improve execution of SAR (Hunt 2015).

The organization and execution of modern SAR operations has been formalized by cooperating nations through the development of guidelines and procedures, lending structure and consistency to SAR missions (Hunt 2015). One such guide resulting from this effort is the International Aeronautical and Maritime Search and Rescue Manual (IAMSAR), a joint publication of the International Maritime Organization and International Civil Aviation Organization. The IAMSAR "provides guidelines for a common aviation and maritime approach to organizing and providing SAR services" (International Maritime Organization 2013) and is regularly updated for use by the international SAR community. Regulations require an up-to-date copy of IAMSAR Volume III to be carried by ships, which contain procedures to follow in the event of their own emergency and also in a situation in which they may be called upon to act as a SAR asset (International Civil Aviation Organization and International Maritime Organization 2013, iii).

This DRM scopes the example SAR mission to a single participating nation in order to establish an organizational and procedural baseline for the DRM and subsequent modeling. Since the United States has been involved significantly in the international SAR community for some time, United States manuals and procedures, such as the National Search and Rescue Plan (NSP) (NSARC 2007, 1) and the National Search and Rescue Supplement (NSS) (NSARC 2000, 1–2), will serve as this baseline.

The IAMSAR and NSS both break down the response of a SAR incident into a sequence of five typical stages that define the kind of assistance provided at any given time as the incident unfolds. Each unique incident may or may not include every stage and the stages themselves can overlap depending on the situation. The five stages along with their definitions are outlined in the table below.

Table 1. SAR Five Stages of SAR Response (from NSARC 2000, 1–2)

Awareness:	SAR system becomes aware of an actual or potential incident.
Initial Action:	Preliminary action taken to alert SAR facilities and obtain amplifying information. This stage may include evaluation and classification of the information, alerting of SAR facilities, preliminary communication checks (PRECOM), extended communication checks (EXCOM), and in urgent cases, immediate action from other stages.
Planning:	Effective plan of operation is developed, including plans for search, rescue, and final delivery.
Operations:	SAR facilities proceed to the scene, conduct searches, rescue survivors, assist distressed craft, provide emergency care for survivors, and deliver survivors to a suitable facility.
Conclusion:	SAR facilities return to their regular location, are debriefed, refueled, replenished, provided with a fresh crew, and prepare for another mission; documentation of the SAR case is completed.

C. OPERATIONAL CONCEPT

A SAR SoS operational concept is featured in the OV-1 diagram in **Figure 2**. The Physical Environment is a sea-based Area of Responsibility (AOR) that includes air, sea and land -based assets. Persons in Distress (PID) are represented by a sinking ship and the hands in the water, threatened by environmental conditions such as heat loss and possible aggressive sea life. A Command and Control (C2) Center is the post for operators, maintainers, contractors, trainers, and potentially senior leaders and commanders. The C2 collects information about the situation, determines the appropriate set of regional assets to call upon for assistance, and chooses the appropriate means of rescue. An On-Scene Coordinator (civil OSC) or On-Scene Commander (military OSC) manages the SAR operation at the scene, usually when multiple assets are involved in the SAR (Hunt 2015). No assumption is made in the OV-1 about which of the platforms contains the OSC; this is one of several open questions to be answered in the analysis. The SAR assets, whether manned or unmanned members of the SoS, collectively monitor and search the environment, to identify other assets and possible threats approaching the area and provide precise location of persons in distress requiring rescue.

SAR Assets may include commercial, defense, and/or private surface vessels, aircraft, condition-monitoring ocean buoys, and other manned or unmanned assets. Robotic and unmanned systems are categorized and depicted as Unmanned Aerial Vehicles (UAVs), Unmanned Surface Vehicles (USVs), and Unmanned Underwater Vehicles (UUVs).

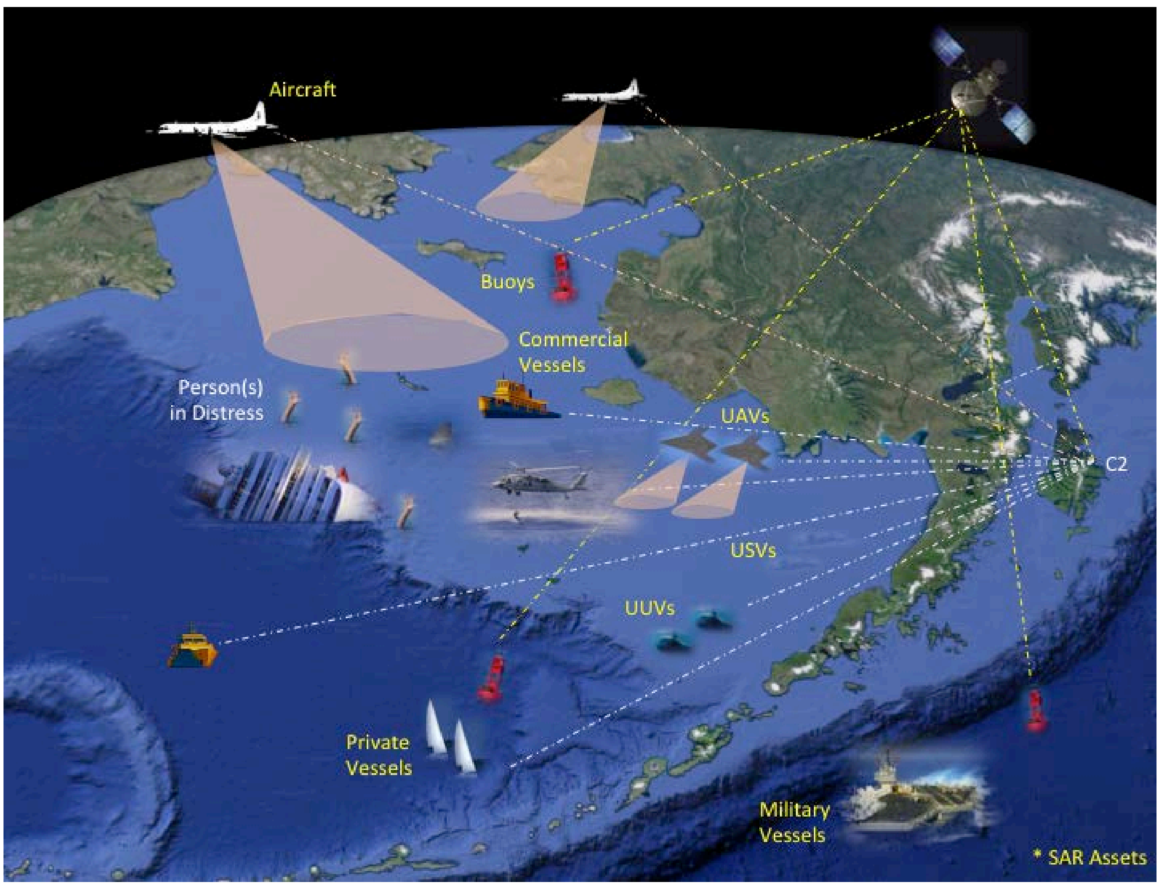

Figure 2. OV-1 Operational Concept for a SAR SoS (after Contag et al. 2013)

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II. PROJECTED OPERATING ENVIRONMENT (POE)

The Projected Operating Environment (POE) is the environment in which the SAR system is expected to operate. This section provides details that describe the environmental conditions, types of locations, and threats to which the system will be subject. The POE establishes a context within which interactions and interfaces among potential solutions to different parts of the system may be modeled to produce measurable outcomes for use in making physical architecture decisions about solution alternatives.

A. ENVIRONMENTAL CONDITIONS

The SAR systems are expected to operate in:

- daytime and / or nighttime
- temperature -50 degrees F and less than 130 degrees F
- icing from clear icing to freezing rain to severe icing
- light to heavy precipitation
- wind gusts up to 70 mph, minor to severe turbulence
- multiple electromagnetic emissions across a range of radio frequency spectra

The DRM will use the United States Coast Guard Air Station Kodiak in Kodiak, AK, depicted in **Figure 3,** as the C2 Center. This location provides SAR capabilities to the nearby waters' commercial and military operations.

Figure 3. Command and Control Center, United States Coast Guard Air Station, Kodiak, AK (Google Maps 2015)

The radius of operation will include the Bering Sea and the Gulf of Alaska (**Figure 4)**. The SAR mission may also be extended to include the North Pacific Ocean, Chukchi Sea, Beaufort Sea, and Arctic Ocean.

Figure 4. SAR Area of Responsibility (AOR) (Google Maps 2015)

B. THREAT DETAILS

1. Assumed Threat Environment

Threats to the success of the SAR mission are primarily environmental in nature. The position of the person(s) in distress may change as a function of currents and tides, and their ability to sustain life in direct contact with water depends on various factors including weather, temperature, sea states, and possible nearby aggressive sea life.

2. Assumed Threat General Conditions

Assumed threat conditions for this DRM are:

a. Maritime Conditions

- sea state: < 5
- water temperature: 38 F

b. Weather Conditions

- wind speed: < 40kts
- visibility: moderate (4km) to excellent (40km)

c. ***Other Conditions***

- waters in the area of the scenario are used for commercial shipping, fishing, and oil drilling.

d. ***Threat Assumptions***

- possible nearby aggressive sea life such as sharks and jellyfish

e. ***Threat Characterization***

- hypothermia protection
  - limited
    - unconsciousness: 30 minutes
    - survival: 90 minutes
  - no protection
    - unconsciousness: 15 minutes
    - survival: 45 minutes

Note: All values used to characterize the POE are notional assumptions after (Contag et al. 2013), and are for academic use only as initial boundaries for an example DRM. Realistic values for an actual DRM would need to be computed from physical models or have a basis in previous analysis.

III. MISSION AND MEASURES

A. MISSION SUCCESS REQUIREMENTS

In order for the mission to be considered successful, all of the following high-level requirements must be met for any SAR system under design. The system under design may be the C2, the OSC, or one or more types of SAR Assets.

- The system under design shall obtain and share available information on location, identity, and status of person(s) in distress until a rescue is completed.
- The system under design shall increase the survival probability of persons in distress until they can receive needed medical attention.
- The system under design shall execute the design reference mission without experiencing a disabling state or malfunction.

B. MISSION DEFINITION

A main reference mission is typically defined to provide a level of detail suitable for collecting measures for assessing the mission success requirements. This mission may have several variants that fall within the analysis scope of the DRM, so a DRM may actually end up containing multiple operational missions or vignettes (despite the singular tense of the document, "design reference mission"). To illustrate the process, an example reference mission is developed for the following capability need statement.

> Civilian and defense agencies need a cost-effective means to search large areas of ocean and over-land terrain in various environmental conditions in order to locate wreckage and survivors in the shortest time possible.

The name of the reference mission will be "Conduct Wide Range Search for Wreckage and Survivors."

A given mission may have different operational situations (OPSITs), which are a collection of variables that define environmental conditions for a mission. OPSITs capture the assumptions being made about the environment in which a mission is to be conducted, so that it is clear to designers under what circumstances the system under design is expected to perform. When a mission is executed in simulation for a given OPSIT, the simulation results inform the design, and may eventually serve as a basis of comparison or a test case during Developmental or Operational Test & Evaluation

(DT&E or OT&E). The OPSITs should not only include a range of nominal situations, but also off-nominal or irregular situations that stress the system under design with realistic scenarios, suitable for verifying that the system's properties are sufficient under all of these expected conditions to perform the mission effectively, or otherwise identify the breaking points of the system. The more OPSITs explored, the better coverage of possible operational environments one has. Information and feedback from Subject Matter Experts (SMEs) is imperative for quality mission and OPSIT development. Missions and OPSITs should be validated by the SMEs, creating a balance between average and extreme situations (Skolnick 2000).

The following four OPSITs pertaining to man overboard and downed aircraft events are excerpted from (Hunt 2015), followed by a mission narrative that is generic enough to apply to each OPSIT. Note that each OPSIT contains a collection of assumptions made about the environment that have implications for logistics, deployment, and time required to achieve the mission. These assumptions are intended to provide an idea of constraints on the mission scenario. Setting values for these variables helps to scope the subsequent mission definition activity undertaken by architects and subject matter experts. Systems engineers use these variables to determine other variables that are key to studying system performance, and values that can be assumed at certain levels until better data is available

1. Man Overboard OPSITs

Whether it is a crab-fishing vessel in the Bering Sea or a nuclear-powered aircraft carrier in the middle of the southeast Pacific Ocean, man overboard situations are a constant threat. While these situations can manifest themselves in a number of ways, it is important to remember that the capability need statement for the DRM specifically mentions searching large areas of ocean. Thus, it makes no sense to conjure a scenario that involves a precisely known survivor location because that type of SAR is not in line with the need statement. As such, the following scenarios are two man-overboard OPSITs, one from a military vessel and one from a civilian vessel. The OPSITs are written in narrative form.

a. Navy Man Overboard Operational Situation

Having finished a straits transit between China and Taiwan, the USS George Washington strike group has been steaming overnight in the direction of Yokosuka, Japan to cap off the end of another yearly deployment. The strike group consists of one cruiser, USS *Shiloh* (CG 67), one destroyer, USS *Mustin* (DDG 89) and the aircraft carrier itself, USS *George Washington* (CVN 73). At approximately 0730 local time, a sailor from USS *Mustin* was reported missing at morning muster by a fellow bunkmate. The subsequent man overboard muster on the ship confirmed that the sailor is indeed no longer on the ship. The last time the sailor was seen was at 2230 the previous night just prior to his final rounds to secure the flight deck. The sailor was wearing a standard float coat containing a sea dye marker, a day and night smoke, flares, a signal mirror and inflatable rubber lobes for flotation. The sailor does not have any anti-exposure protection. The average ambient temperature is 90°F (32 °C) and the sea surface temperature is 82 °F (28 °C). Sea state for the last 12 hours was reported at 2 on the Douglas Sea State Scale (1-3 feet of wave height). Current conditions are sunny with a visibility of 10 miles and winds out of the north at 5 knots. From 2230 to 0300, the strike group was steering 090 magnetic and at 0300 made a turn north to 020 magnetic and have been on that course ever since. The strike group's speed has been constant at 20 knots. There have been no detectable signals from the EPIRB on the sailor's float coat. The assets available are all three ships, which each have a rigid inflatable boat rescue crew, two MH-60S helicopters and one E-2C Hawkeye off of the aircraft carrier. Both helicopters are fully equipped with a rescue swimmer and all the necessary equipment to execute a SAR and Lightning 617, the senior crew of the two, has been tasked as the OSC.

b. Civilian Man Overboard Operational Situation

It is the middle of another king crab season in the Bering Sea. At 2145 local time, a distress call is received from a fishing vessel that has caught on fire in heavy seas due to malfunctioning equipment. At that time, a set of approximate coordinates were transmitted. At 2300, the final distress call stated that all six crewmembers were abandoning the ship due to the out-of-control fire. The final distress call does not contain an updated set of coordinates. All six crewmembers are equipped with anti-exposure protection against hypothermia, personal flotation, flares, smokes and a raft that fits all six. Current conditions are overcast with a ceiling of 1000 feet and a visibility of seven miles. Illumination levels for the night are at 23% and winds are heavy out of the west at 50 knots. Ambient air temperature is -7 °F (-22 °C), the wind chill temperature is -43 °F (-41 °C) and sea surface temperature is 38 °F (3 °C). Sea state is a seven on the Douglas Sea State Scale (20-40 feet of wave height). Available assets include one Coast Guard SH-60F helicopter that is 90 minutes away from the original set of transmitted coordinates along with two other nearby fishing vessels that are 20 and 35 nautical miles away respectively from the original set of transmitted coordinates. The Coast Guard helicopter, Calumet 610, is fully SAR capable and has been tasked as the OSC.

2. Downed Aircraft OPSITs

Another common SAR initiating event is that of a downed aircraft. Most modern aircraft have onboard equipment that transmits location data to controllers, and in all controlled airspace, radar operators have real-time data on display to show precise aircraft locations in space. If this were not enough, pilots are required to file flight plans with various agencies so that if something were to go wrong, rescuers would have an intended route of flight at a minimum. For all these safeguards however, aircraft still go missing for various reasons to include malfunctioning equipment, bad weather and flights into uncontrolled airspace (i.e., long transits over water or low-level routes through mountainous terrain). For this reason, downed aircraft scenarios are a great fit to the need statement of searching large areas of water and land for wreckage and survivors. Like the man overboard situation, the initiating event of a downed aircraft will be viewed from both a military and civilian scenario to ensure completeness within the DRM. The downed aircraft OPSITs are also presented in narrative form.

a. Navy Downed Aircraft Operational Situation

Two F/A-18E Super Hornets were practicing gun maneuvers during normal carrier cyclic operations. Their practice runs were being conducted on a Mk-58 marine location marker smoke that was dropped off the aircraft carrier’s 120 radial for 51 nautical miles. At approximately 1430 local time, there was a mid-air collision of the two aircraft at 9000 feet above ground level. Before ejecting, one pilot made a mayday call but provided no coordinates or position update. There have been no radio transmissions from survival radios and no hits off any emergency location devices. Current conditions are sunny with haze, no cloud layer and eight miles of visibility. Winds aloft are 270 degrees at 19 knots. Ambient air temperature is 79 °F (26 °C), sea surface temperature is 68 °F (20 °C) and sea state is a three (three to five feet of wave height) on the Douglas Sea State Scale. Each pilot is equipped with personal flotation and a survival vest that contains sea dye, signal mirrors, day and night smoke, flares and a reflective helmet. Neither pilot has anti-exposure equipment. Available assets are two airborne MH-60S plane guard helicopters, one E-2C Hawkeye and a destroyer that is 20 nautical miles east of the aircraft carrier. Both helicopters are fully SAR capable and the most experienced crew, Lucky 620, is tasked as the OSC.

b. Civilian Downed Aircraft Operational Situation

A private pilot filed a low-level VFR flight plan from a Colorado ski resort back to his home airfield. The departure point was Crested Butte Regional Airport and the destination was Centennial Regional Airport, just outside of the city of Denver. Total flight distance measured approximately 200 miles with a flight time of approximately 90 minutes. The pilot's intended route included several visual checkpoints from the chart. Approximately two hours past the filed landing time and after several attempts to contact the aircraft via emergency frequencies, the local flight service station initiated its missing aircraft protocol. The last agency to speak with the aircraft was the tower controller at Crested Butte Regional upon departure at 1200 local time. Current time is 1530, weather is sunny with 10 miles of visibility. Winds are variable at 15 knots gusting to 25 knots. Ambient air temperature is 23 °F (-5 °C) with an overnight low of 5 °F (-15 °C). The type of aircraft is a four-seat Piper Warrior II prop plane and the manifest states three people on board. The status of survival equipment on the aircraft is unknown and there have been no transmissions from any emergency beacons. Search assets on hand include two fully-crewed Bell-207 rescue helicopters, two Cessna-152 fixed-wing propeller planes and various ground units located anywhere from 20 to 50 miles away all along the intended route of flight. Due to their capabilities and experience, a seasoned crew from one of the helicopters, call-sign Landslide 07, is tasked as the OSC.

C. MISSION EXECUTION

Once OPSITs have been defined, the reference mission is decomposed into the individual operational activities necessary for execution of the concept depicted in the OV-1.

Working with operational SMEs, system architects must map out the steps that are taken to accomplish the mission from an operational or business perspective. A mission consists of multiple operational activities, and its execution typically involves multiple operational nodes (a.k.a. actors, performers, or assets) concurrently conducting a variety of assigned operational tasks (specific, measurable activities). The product of the mission analysis is a narrative sequence that details the activities to be assigned to the nodes in order to complete a mission. The activities and actors should be described as independent of solution as possible to allow the mission execution sequences to serve as a baseline for comparing multiple competing concepts for alternative solutions. The mission narrative may be rendered in different graphical views, all of which depict the actors and tasks required to implement the mission commander's ConOps. The commander determines the tasks that are essential to mission success and identifies these as Mission Essential Tasks (MET). The MET may be derived from common task lists that capture the doctrine for executing typical missions, including the Universal Joint Task List (DoD UJTL 2014), Universal Naval Task List (DoD UNTL 2007), and Marine Corps Task List (DoD MCTL 2015). Other services have common task lists as well; for examples, see the Army Universal Task List (DoD AUTL 2012), and the Air Force Task List (DoD AFTL 1998).

The following mission narrative describes the reference mission "Conduct Wide Range Search for Wreckage and Survivors." "If-then" logic is incorporated into the narrative to show possible alternate paths that could occur during mission execution as the various nodes perform actions and make decisions. The sequenced steps include numerical suffixes to ease in the translation of the narrative into various models. Any events that are recurring, or that can occur at any point during the mission, are denoted separately from the "if-then" sequence as general rules. This separation simplifies modeling diagrams since the general rules may be modeled separately or assumed, as appropriate for the analysis at hand. They are also useful for evaluating different concepts because they allow for multiple iterations to be tested, as instances of the general rules can be injected at any point in the mission scenario.

1. "Conduct Wide Range Search for Wreckage and Survivors" Mission Narrative

- Command and control (C2) either receives a distress signal from a person in distress (PID) or is notified of a missing person or vessel. (1)

- If the general location information falls outside of the C2's area of responsibility (AOR), the mission is assigned to the appropriate entity. If the general location is within the C2's AOR, C2 initiates SAR protocol and passes mission information to available assets. (2)

- SAR Assets (SAs) deploy to the search area as assigned by C2 and the designated on-scene commander (OSC) attempts to contact the PID or the missing person or vessel. If contact is made, the OSC requests a precise location and situation report (SITREP). If no contact is made, the OSC will periodically try again. (3)

- Upon reaching the search area, datum or last known location (LKL), OSC initiates a search pattern based on the mission situation to include environmental conditions, available assets, crew composition and time on station. (4)

- OSC conducts the search plan and all assets involved in the search pattern scan the environment for any signs of the PID or vessel. All other SAR Assets report directly to OSC. (5)

- If any SA spots an object of interest, that SA maneuvers for a closer inspection. If the object of interest appears to be wreckage, the SA notifies OSC and OSC notifies C2 of the situation. If object of interest appears to be a PID, then the SA notifies OSC and maneuvers to rescue or has OSC coordinate with another SA to make the pickup. If the object of interest is not related to the SAR mission, the SA resumes the search pattern until spotting another object of interest or conditions are reached for a return to base (RTB). (6)

a. General Rules

- Throughout the mission, all assets constantly monitor bingo conditions—the point at which the unit is no longer SAR capable and has just enough fuel remaining to execute a safe and successful RTB—and provide on-station time updates to OSC who communicates with C2. As an SA approaches bingo conditions, they will request a replacement if available and upon its arrival, execute an RTB.

- At any point in the mission, the OSC may receive SITREPs or maneuvering commands from C2. OSC provides regular SITREPs to C2.

- At any point in the mission, the OSC may request a SITREP from C2, especially if a significant length of time has elapsed since an update was received.

- At any point in the mission, if the OSC receives information containing the location of the PID or vessel, then it confirms receipt, proceeds to the LKL or tasks an SA to proceed to the LKL and provides a SITREP to C2.

- At any point in the mission, if an SA experiences a condition or system failure rendering it unsafe or ineffective at accomplishing the mission, the SA notifies OSC and executes an RTB. OSC will coordinate with C2 for a replacement SA as applicable.

- If survivor(s) are found, the SA provides the condition of each survivor rescued to OSC who will pass the information to C2 so that medical follow-on treatment can be coordinated.

- In multiple survivor situations where survivors are separated, if a rescued survivor provides updated information on the location of other survivors, the SA notifies OSC, OSC notifies C2 and OSC and adjusts the search plan and pattern as necessary to include the new information.

- In cases where the OSC is the only SA on station, the OSC assumes all mission responsibilities outlined above including making the rescue if able. If unable, OSC remains on station as long as possible for coordination and assistance until an SA arrives that can make a rescue or the OSC is relieved by a more capable platform.

D. MEASURES

This DRM is designed to provide the operational background and expectations for a system under design or analysis necessary to assess system capabilities in the context of the above SAR reference mission. To provide quantitative results and recommendations, measures must be defined to assess the effectiveness and performance of different possible solution concepts in meeting the mission success requirements. There may be many solution concepts capable of meeting the mission success requirements; in this case, the question focuses on which is the best of the proposed solutions. To define "best," stakeholder interviews and requirements elicitation methods are employed to gather the important system characteristics that can be used to discriminate the suitability of each system in executing this mission. For the purposes of this DRM, the top ranking system characteristics (assuming a method such as the Analytic Hierarchy Process (AHP) (Saaty 2008) has been employed) are summarized here:

- Interoperability
- Safety
- Security
- Lifecycle cost
- Environmental impacts
- Reliability
- Maintainability
- Availability
- Ease of use
- Adaptability for employment in multiple OPSITs

Using a Quality Function Deployment (QFD) method (Chan and Wu 2002), specific measures can be selected and mapped to the above high level suitability characteristics. The common lists are a ready source for operational activities and their corresponding measures. The following measures have been selected directly from the UNTL and MCTL, respectively, for assessing mission success for the OPSITs in this DRM.

NTA 6.2.2.1 Perform Search and Rescue (SAR)

To employ aircraft, surface ships, submarines, specialized rescue teams, and equipment for search and rescue (SAR) of personnel in distress on land or at sea. (JP 1, 3-0, NDP 1, 6, NWP 1-02, 3-50.1 Rev A)

M1	Hours	To reach area of isolated personnel after *Go* decision.
M2	Hours	To rescue a survivor or isolated person.
M3	NM2	Search area coverage.

MCT 6.2 Rescue and Recover

The use of aircraft, surface craft (land or water), submarines, specialized rescue teams, and equipment to search for and rescue personnel in distress on land or at sea. Marine Corps aviation forces may be tasked to perform self-supporting Search and Rescue (SAR) operations and some external SAR support. SAR is a secondary task for tactical aviation units, and its execution should not detract from primary warfighting functions. (JP 1, 3-0, 3-05, 3-50 Series, MCWP 2-6, 3-2, 3-11.4, 3-24, 3-25.4, NDP 1, 6, NWP 3-50.1 Rev A, NTA 6.2)

M4	Percent	Of personnel sending SAR distress signal, rescued.
M13	Number	Of personnel and equipment available to respond.
M15	Number	Of sorties required to execute SAR mission.

E. SUMMARY OF DRM ANALYSIS OBJECTIVES

This DRM has been developed to support the answering of the following primary analysis question:

> How could robotic / unmanned system(s) be employed to increase SAR mission success, while maintaining or reducing lifecycle costs, as compared with an architecture that does not utilize robotic / unmanned systems?

(Hunt 2015) and (Steward 2015), which contain representative Model Based Systems Engineering (MBSE) analyses based on this DRM, are recommended as further reading for understanding how a DRM can be used to support structured and systematic architectural analysis.

IV. TAKE AWAYS

A. DRM ELEMENTS

Designing a reference mission is a method used to understand the environment surrounding the mission analysis. A reference mission includes a capability need, a deployment of systems, a physical environment in which the mission takes place or is executed, and whatever changes the environment will undergo as the scenario progresses. The operational concept must be understood, so that it can eventually be used as a baseline against which different system concept alternatives will be assessed. Alternatives are to be assessed in terms of how well each addresses the same operational concept, to provide for a uniform comparison with the mission success requirements and against each other.

The order in which the DRM elements are developed may differ from effort to effort. This is because architecture design and analysis is an iterative, nonlinear process that unfolds based on the specific needs of the sponsor/customer, and the information available. There is no one-size-fits-all architecting process model to learn or teach that is optimal for every project. With practice, one will develop a familiarity with the elements that need to be present, and when it is appropriate to insert them.

The DRM method is consistent with (though less extensive than) the upfront portions of the Joint Capabilities Integration and Development System (JCIDS) – the DOD's current capabilities-based acquisition process. Enclosure B of the JCIDS Manual (DOD 2012) describes the elements of an Initial Capabilities Document (ICD), which parallel the elements in the DRM. This reference is provided for context on where the DRM method would fit within a larger acquisition process.

B. STATEMENT OF A CAPABILITY NEED

A capability need is a solution-neutral statement about what the stakeholders want the system under design to deliver, overall. It should contain no mention of an assumed solution to meet the need, except as already constrained by previous and well-documented decisions. A well-written capability need is clear and concise, and makes no assumptions about preconceived solutions. To enable maximum number of design possibilities, flexibility and creativity, describe a capability need in the most solution-free terms possible.

Formulating a good capability need statement for a real project requires research, iteration, and patience. Keep in mind that not all capability needs require a new materiel solution to be procured. A full Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) analysis is usually completed prior to making a determination on whether a materiel solution (new physical system) is actually needed.

C. SUMMARY

The DRM has established:

- an operational context, description(s) of the environment and situations in which a system of interest is expected to operate,
- an operational narrative containing enough detail to generate multiple operational scenario variants,
- a sequence of operational activities and interactions between each system and other systems in its environment, and
- measures for establishing goals for mission success.

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