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WHITE SANDS MISSILE RANGE NON-TRACK OPTICS: STREAMLINING THE PROCESS OF CONDUCTING BUSINESS FOR IMPROVED CUSTOMER SUPPORT

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December 2013

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Budget overruns and scheduling difficulties within the White Sands Missile Range (WSMR) test community have become more prevalent of late. Two of the biggest customer complaints have been that WSMR is too expensive, and that the scheduling process is slow and inflexible; the WSMR Non-track Optics organization has been suggested as the main contributor to these problems.

WSMR Non-track Optics manages multiple types of specialized static cameras, networking instrumentation, and vehicles to transport and control its equipment, but has shown itself unable to support numerous test activities scheduled during the same timeframe.

The focus of this thesis is to define the process whereby requirements for Non-track Optics support are routed, identify process inefficiencies within the organization, and recommend solutions for the Non-track Optics organization to successfully adopt the “pull” method, where the ability to set-up instrumentation and support exactly what the customers want, when they need it, is achieved within budget. In identifying and addressing these inefficiencies, solutions can be applied resulting in WSMR becoming a more affordable and customer-oriented test range.

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ABSTRACT

Budget overruns and scheduling difficulties within the White Sands Missile Range (WSMR) test community have become more prevalent of late. Two of the biggest customer complaints have been that WSMR is too expensive, and that the scheduling process is slow and inflexible; the WSMR Non-track Optics organization has been suggested as the main contributor to these problems.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABT	air breathing threats
ATEC	Army Test and Evaluation Command
AUR	all up round
BDO	Business Development Office
CAS	control activation system
CFT	captive flight test
COMSEC	communications security
DOAMS	Distant Object Attitude Measurement System
DoD	Department of Defense
DOF	day of flight
DS	data science
DSL	data science limitation
ECM	electromagnetic compatibility
FF	fire-and-forget
FRC	flight readiness checks
FTS	Flight Termination System
FY	fiscal year
GEU	Guidance Electronics Unit
GLS	Ground Launch System
GMLRS	Guided Multiple Launch Rocket System
HIMARS	High Mobility Artillery Rocket System
HTK	hit to kill
IM	information management
IMCOM	Installation Management Command
IRCC	Inter Range Control Center
JAGM	Joint Air To Ground Missile
JAP	Joint Applied Project
KTM	Kineto Tracking Mount
LATS	Launch Area Theodolite Systems
LOAL	lock-on after launch
LOBL	lock-on before launch

MATS	Multimode Automatic Tracking Systems
MDAGS	modular digital airborne guidance section
MFOM	MLRS family of munitions
MLRS	Multiple Launch Rocket System
MMW	millimeter wave
MT	material test
MTM	Maneuvering Tactical Missile
OR	operational requirements
RE	range engineer
RO	range operations
ROM	rough order of magnitude
PAAT	patriot as a target
PAC3	patriot advanced capability 3
POC	point of contact
PP	precision point
PRAT	project review and assessments team
RF	radio frequency
RP	rocket pod
RPL	rocket pod container
SDI	strategic defense initiative
SME	subject matter expert
S&A	Safe and Arming Device
TACLANE	tactical local area network encryption
TBM	Tactical Ballistic Missile
TM	telemetry
TO	test officer
TRMS	Test Resource Management System
TSN	Test Support Network
TSN-IP	Test Support Network Internet Protocol
VTM	versatile tracking mounts
WSMR	White Sands Missile Range
WSTC	White Sands Test Center

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We appreciate all of those who supported us in any respect during the completion of the project. In conclusion, we recognize that this research would not have been possible without the opportunity that has been afforded us to grow and mature intellectually in this master of science program. It is with our most sincere gratitude and appreciation that we thank all the instructors and staff that comprise the Naval Postgraduate School.

Last, we must also thank the truly supportive and diverse group of students with whom we traveled this journey during this program. The knowledge, skills, and experience of those students proved to be equal in value to the lectures and lessons that were provided in the program.

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I. INTRODUCTION

A. BACKGROUND

White Sands Missile Range (WSMR) is a test range that provides DoD agencies, foreign militaries, private industries, and academic fields with an extensive infrastructure and data collection capability for testing a multitude of developmental systems to further strengthen National Defense. WSMR is located in Southern New Mexico and is composed of over 2.2 million acres, which makes it attractive to customers requiring an abundance of land and airspace as shown in Figure 1 (*U.S. Army White Sands Missile Range Customer Handbook*, 2010, p. 6-9). WSMR population in 2010 was 1,651 with 17% of the population being engineers. Most common industries in 2007 through 2011 were public administration (27%), professional, scientific, and technical services (23%), manufacturing (13%), and transportation and warehousing (7%) (*White Sands, New Mexico (NM 88002) profile: population, maps, real estate, averages, homes, statistics, relocation, travel, jobs, hospitals, schools, crime, moving, houses, news*, n.d.). The highly diverse, natural environment with all terrain types are further augmented with an extensive array of threat-representative ground and airborne targets, as well as infrastructure targets, cave networks, deeply buried structures, and employment of realistic electro-magnetic and ECM environments. WSMR is also populated with over 3,000 permanent data collection sites, extensive instrumentation equipment, and a data processing facility for real-time and deferred test data processing. As the largest open-air land test range in the DoD, WSMR consists of multiple instrumentation and data collection capabilities, such as timing signals, target support, telemetry, flight safety, hazardous explosive tests, calibration and standards, photography and film processing, trajectory, attitude and event measurements, communications throughout the range, recovery of components, report preparation, and data evaluation (*U.S. Army Whites Sands Missile Range Capabilities Handbook*, 2009).

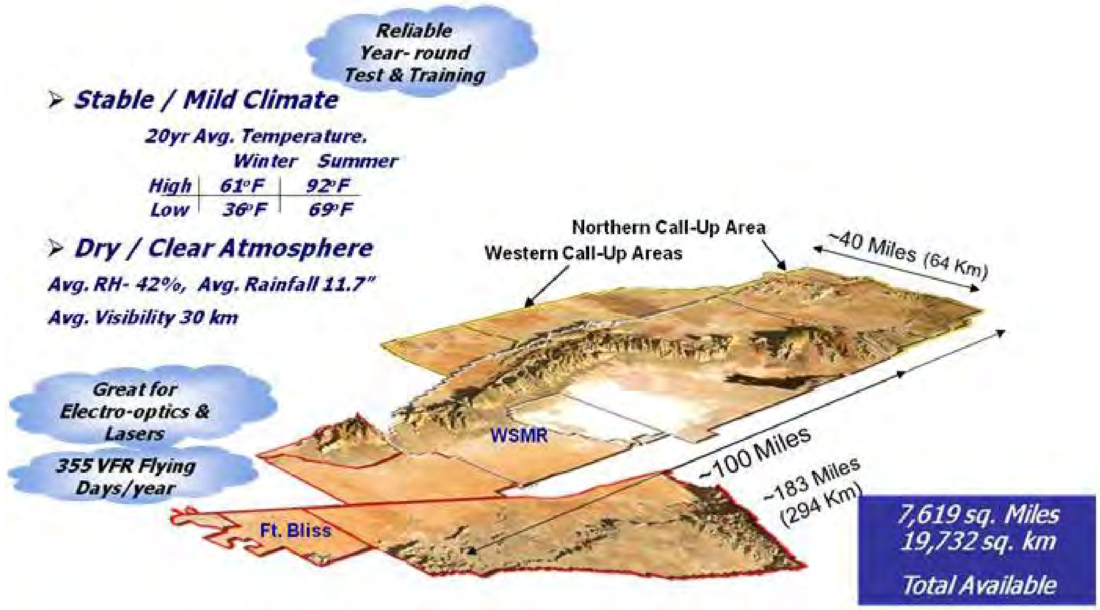

Figure 1. WSMR Land Space and Climate (from *U.S. Army White Sands Missile Range Customer Handbook*, 2010, p. 7)

Within WSMR, there are two main organizations, U.S. Army Installation Management Command (IMCOM) and White Sands Test Center (WSTC), with different directorates which have distinct responsibilities when it comes to converting customer requirements to actual data collection as shown in Figure 2. WSTC is shown as the “Test Center Commander” in the center green box in Figure 2 and IMCOM is shown as “Garrison Commander” in the orange right box in Figure 2. The WSTC, which is the primary focus of this JAP, is responsible for overall planning and execution of test and evaluation missions. Three of the main WSMR directorates are the materiel test (MT), range operations (RO), and information management (IM).

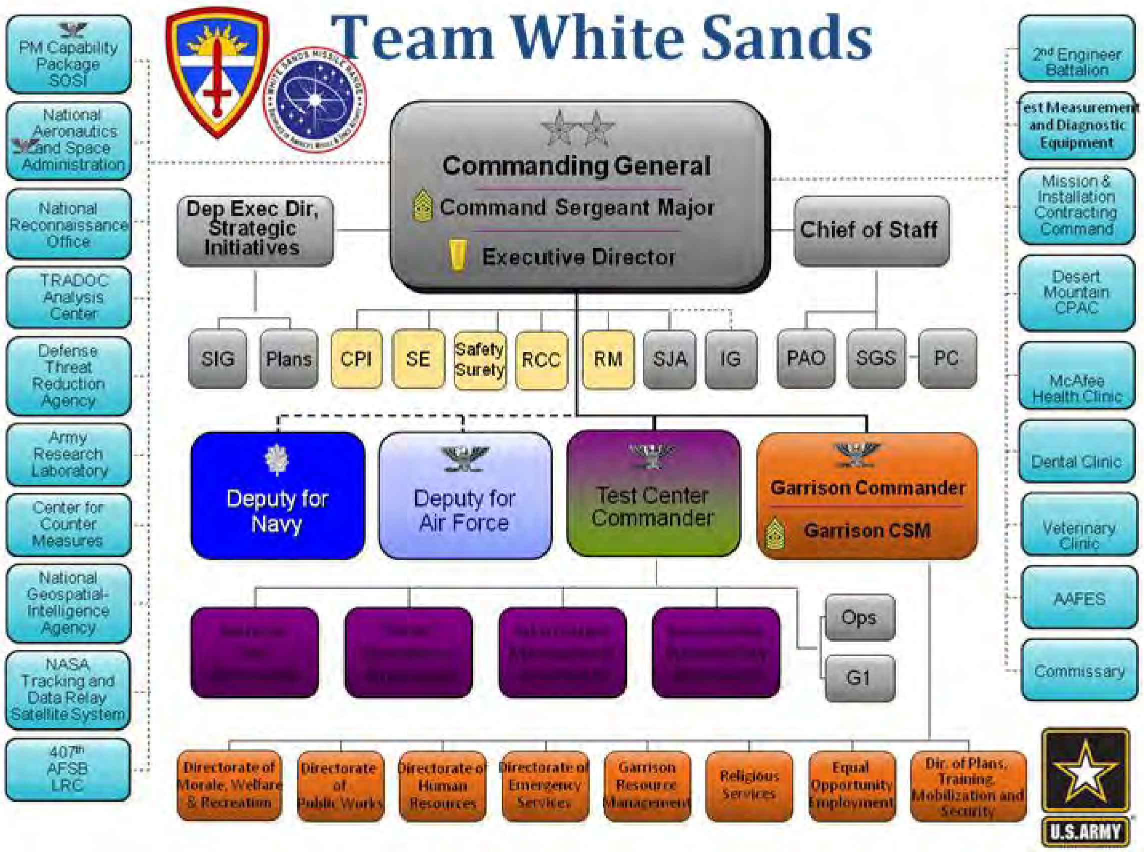

Figure 2. WSMR Organizational Chart (from *U.S. Army White Sands Missile Range Customer Handbook*, 2010, p. 9)

The MT Directorate is the testing arm of WSMR. MT's organizational chart is provided in Figure 3. MT provides evaluation of Army systems, materiel and equipment through field and laboratory testing. MT is the organization that interfaces directly with the customer and characterizes the customers' requirements into the operational requirements (OR) document.

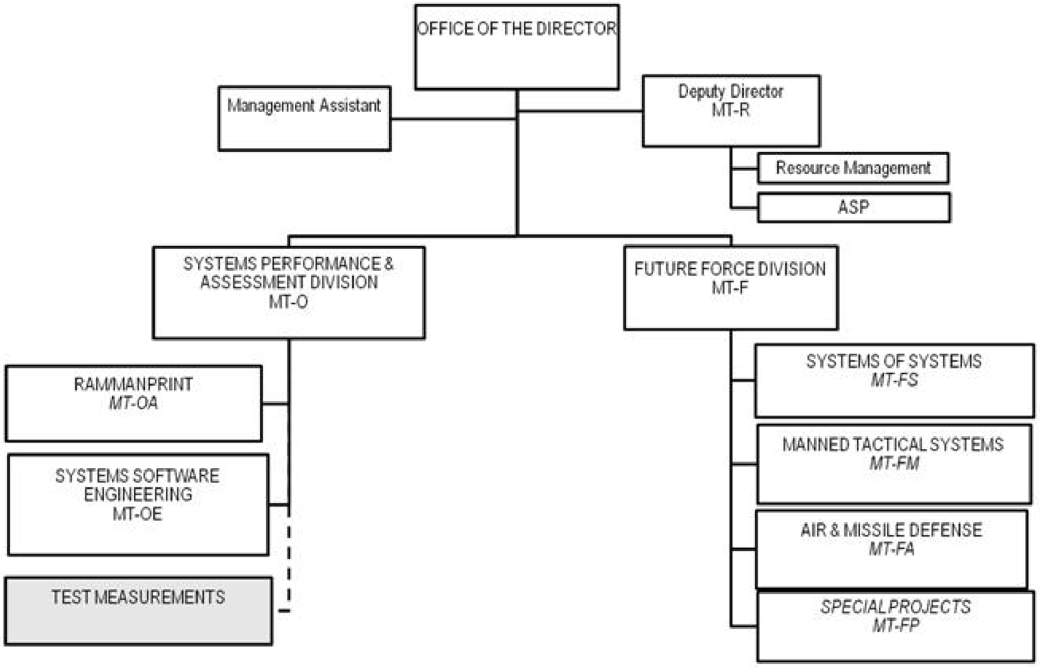

Figure 3. MT Directorate Organizational Chart

The range operations (RO) directorate establishes and implements policies; manages the range schedule, programs, and procedures; and develops an acquisition for range instrumentation, range operations, data measurements, data reduction, and complete flight safety services. The RO directorate organizational chart is provided in Figure 4. RO receives the OR from MT and is responsible for managing and scheduling the range's data collection assets. RO's schedulers and MT's test personnel meet on a weekly basis to formulate a range test schedule for a month in advance. It is the responsibility of the RO scheduler to ensure efficient range utilization, taking into consideration program and mission priorities, so that instrumentation support groups are employed to their maximum capacity. RO's data collection branch must satisfy the requirements for data collection and data analysis, as defined within the OR. The RO data collection branch is composed of various instrumentation support groups, including optics, radar, and telemetry. The optics instrumentation array consists of Multimode Automatic Tracking Systems (MATS), versatile tracking mounts (VTM) and a version of the Contraves-developed Kineto tracking mount (KTM). The KTM collects video data of the tracked object's image, azimuth and elevation angles. The Battle Space Real-Time

Video System collects video from elevated gimbals units on towers. The collected optics data also include attitude, event, and miss-distance information. Other optics applications include radiometry, laser detection and analysis, and low-cost sacrificial high-speed target interior imaging. The optical instrumentation array is complemented with the Distant Object Attitude Measurement System (DOAMS), Launch Area Theodolite Systems (LATS), mobile telescopes, fixed cameras (from here on referred to as Non-track Optics), and closed circuit television.

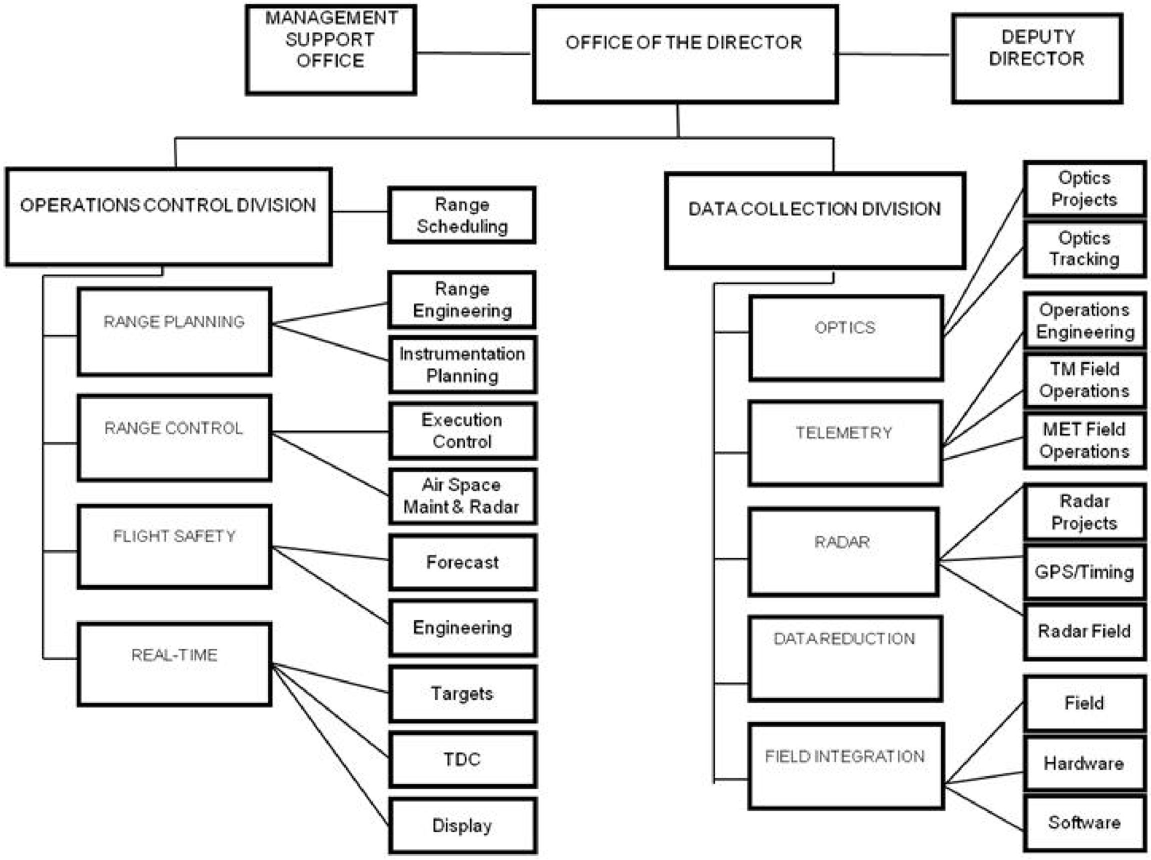

Figure 4. RO Directorate Organizational Chart

The information management (IM) directorate operates and maintains the WSMR real-time and post-test network hardware and software systems. The network is utilized by WSMR customers to distribute and collect test data at different locations throughout WSMR. The IM directorate organizational chart is provided in Figure 5. In addition, IM provides the state-of-the-art, real-time processing and display of both range instrumentation and telemetry data for range customers, as well as post-test analysis.

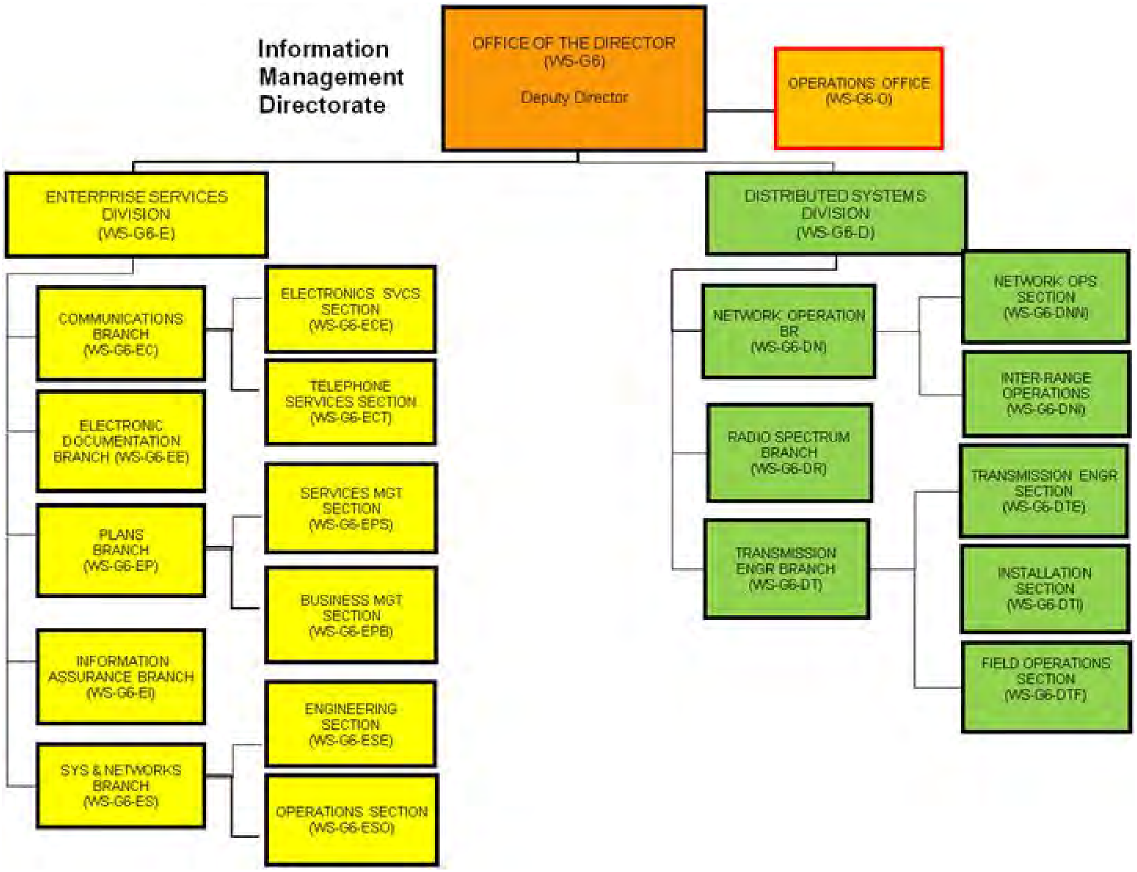

Figure 5. IM Directorate Organizational Chart

The above narration introduces the complexity of doing business at WSMR, illustrating the importance of all test team members working together for a well-engineered business process. A test range should be able to adapt and execute in an efficient manner in order to receive customer satisfaction, with an acceptable cost in range operations. However, customer surveys, past experience, and mission cost data have repeatedly pointed out inconsistencies and discrepancies with the method on which WSMR currently conducts business. WSMR customers have often adjusted their overall project’s schedule, and conferred with the range, to investigate the availability of WSMR Non-track Optics resources during a requested time frame. Because of this, the Non-track Optics organization specifically, have been scrutinized for being inefficient and over the allotted budget. The correct tools and a solid process for scheduling this type of support element do not seem to exist, and this has become evident when costs increase and the number of tests conducted at the range decline.

Organizational behavior is defined as, "field of study that investigates the impact that individuals, groups, and structure have on behavior within organizations, for the purpose of applying such knowledge toward improving an organization's effectiveness" (*Essentials of organizational behavior*, 2012, p. 2). This JAP will concentrate on conducting an organizational structure analysis specific to the Non-track Optics organization. After conducting a comprehensive study of the Non-track Optics organizational processes, an understanding of the specifics issues will be revealed. The findings could ultimately be utilized in a future development of a strategic plan specifically formulated to make the Non-track Optics organization more efficient.

B. OBJECTIVES

The objectives of this research are as follows:

- To define the existing structure and process flow of WSMR's Non-track Optics organization, from written customer request to the actual operator support in the field.
- To collect valid data on Non-track Optics' business process and structure.
- To determine the specific areas in the Non-track Optics organization that have the greatest impact on mission cost and scheduling conflicts.
- To make final recommendations on needed changes to WSMR's Non-track Optics organization that will reduce customer costs and improve effectiveness and efficiency.

C. RESEARCH QUESTIONS

The overall research questions to be addressed for this particular JAP are as follows:

- What is the current Non-track Optics organization business process and how much does it cost?
- Is the current Non-track Optics organization business process efficient?
- What are the major problems associated with the current Non-track Optics organization business process?

- How are organizations or WSMR directorates affected by these problems?
- What should be done to correct the major problems and how will these actions mitigate problems being experienced?

D. SCOPE

This thesis will focus on the Non-track Optics organization business process and its associated costs using three specific programs previously conducted at WSMR: Joint Air to Ground Missile (JAGM), Guided Multiple Launch Rocket System (GMLRS), and patriot advanced capability 3 (PAC 3). Additionally, because this Joint Applied Project (JAP) focuses primarily on the program management and not on technical aspects, classified portions of these programs will not be included. The systems described herein may be in a historical configuration which may have evolved to a different system at present day.

E. LITERATURE REVIEW AND METHODOLOGY

In the past, "data calls" were initiated by WSMR management in an effort to gain a better understanding of the problems portrayed in this JAP. Our ensuing research will include the collection of existing data (i.e., customer post-mission surveys, cost reports, and existing policies of conducting business), with the anticipation of identifying and justifying any existing problems with the current Non-track Optics organization business process. Once evidence is found which confirms a business problem, the data will be processed through analytical models in order to identify where the issue truly exists. The types of Non-track Optics parameters that will be analyzed are as follows:

- Time to develop support plans
- Instrumentation set-up times
- Personnel travel time between base locations to mission specific sites
- Labor costs and time to support each mission task, to include immediate delivery of data products to the customer
- Instrumentation tear-down times
- Standard operating procedures
- Mission logs detailing the procedures for interfacing with other WSMR support groups

- Schedule logs that revealed when mission schedules were changed due to Non-track Optics support

After gathering sufficient data, an in-depth analysis will take place. The first objective will be to attach data and facts to the Non-track Optics organization efficiency. A detailed process map describing incoming customer requirements, range mission planning, execution, and reporting will be broken down in an effort to identify deficiencies that will be specific to the Non-tracks Optics organization. Next, a list of root causes will be attached to each deficiency. Data on the major root causes will be collected for conducting process and data analyses. Finally, after researching and analyzing all the data, conclusions emerged and solutions will be suggested.

F. DEFINITIONS

Concepts used in this JAP are based on acquisition management, strategic management, organizational structure analysis, and terminologies, which are portrayed in the following three programs: JAGM LM F2A, GMLRS UPVT-9, and PAC 3 vs. PAAT P7–4. These programs are analyzed within this JAP document. Army definitions, as well as acronyms, of acquisition and program terms are provided throughout this document, where needed.

1. JAGM

The Joint Air-to-Ground Missile (JAGM), shown in Figure 6, is a common air to-ground precision guided missile for use by joint service manned and unmanned aircraft to destroy high-value stationary; moving and maneuvering; and relocate able land and naval targets. JAGM is required to provide a common, multi-mode weapon capable of providing both current and future aviation platforms with reactive targeting capabilities satisfying the sum of needs across the joint platforms, and eliminate the requirement for separate upgrades to multiple existing missile systems. The JAGM will replace the HELLFIRE family of missiles (*PEO Missiles and Space Weapons Systems Book, 2012*, p. 65).

Figure 6. Joint Air-to-Ground Missile (JAGM) (from *PEO Missiles and Space Weapons Systems Book,* 2012, p. 65)

The test support that WSMR provides includes optics (tracking and non-tracking), telemetry, radar, meteorology, range control, and communications support. The data products provided by WSMR personnel are provided in Table 1.

JAGM Data Products	
Raw Data	safety/surveillance video
	radar data
	telemetry data stream
	telemetry data scale factors and descriptions
	meteorological data
	Non-track optical data
In-Test Data	TM plots
	TM displays
	TM raw data stream digital tapes
	decoded TM digital data
Frequencies	telemetry
	MMW radar operating frequency band
	MMW radar center frequency
	MMW radar frequency bandwidth
	MMW radar transmit power

Table 1. JAGM Data Products

2. GMLRS

The GMLRS unitary rocket is part of the MLRS family of munitions (MFOM). It is a product improvement in the family of guided rockets intended to accommodate different types of payloads. The baseline GMLRS Unitary rocket deploys a highly explosive warhead for point or delayed detonation modes of operation. It is a product improvement in the family of guided rockets intended to meet the system goal of integrating a filled explosive warhead into the GMLRS rocket.

The GMLRS rocket pod (RP) is comprised of a rocket pod container (RPC) and GMLRS development flight test rockets, as shown in Figure 7. The RP is capable of holding six (6) GMLRS development flight test rockets, but for test purposes, it contains the number of GMLRS rockets required to support a particular mission. The GMLRS RP is loaded into either an M270A1 or a HIMARS launcher, from which the GMLRS rocket(s) is launched.

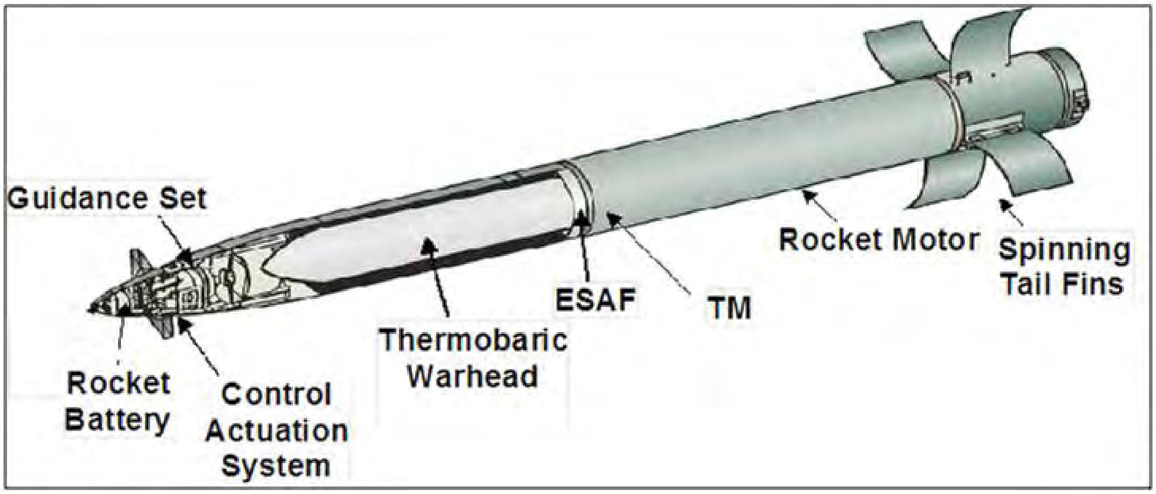

Figure 7. GMLRS Major Subsections (from *Operations requirement No. 34323: Guided Multiple Launch Rocket System (GMLRS)*, 2011, p. 6)

The Guided Multiple Launch Rocket System (MLRS) unitary rocket (GMLRS Unitary) preflight testing and flight test missions associated with this particular test were conducted from an M270A1 or High Mobility Artillery Rocket System (HIMARS) launcher. One, three and six rockets were ripple launched from an M270A1 (or

HIMARS) launcher positioned in a level attitude. After launch, the rocket flew an approximate 40-kilometer guided profile from launch site to impact site, where the payload event occurred. The test support that WSMR provided included optics (tracking and non-tracking), telemetry, radar, meteorology, range control, and communications support. The data products provided by WSMR personnel are provided in Table 2.

GMLRS Data Products	
Raw Data	Radar Tapes
	Telemetry Tapes
	Non-Track Optical Data/Fixed Camera Film
In-Test Data	Trajectory Plots
	Trajectory Tapes
	Telemetry Plots
	Telemetry Tapes
Post-Test Data	Trajectory
	Miss Distance
	Telemetry
	Events or Time
	Geodetic Survey Computation
Frequencies	Telemetry
	Proximity Sensor
Documentary and Aerial Photography	Stills
	Motion Picture
Recovery	Location
	Hardware
Recovery Aid	Radar Look Angles to Impact Point
	Radar Range to Impact Point
	Non-Track Optical Look Angles to Impact Point
	Telemetry Look Angle At Loss of Signal
Other Items	Test Results of Rocket Assembly and Checkout

Table 2. GMLRS Data Products

3. PAC-3

The PAC-3 missiles are small, robust, agile interceptors with an operating envelope compatible with the tactical missile threats as shown in Figure 8. SDI-developed technologies were utilized in the design of these small, lightweight, agile missiles, with performance and capability sized for Tactical Ballistic Missiles (TBM), Maneuvering Tactical Missiles (MTM) and Air-Breathing Threats (ABT). The missiles are sized for transportability and provide a large launcher load-out capability. It achieves its target kill by direct body-to-warhead impact. They are hit-to-kill (HTK) missiles.

Each missile performs fly-out using inertial guidance, homing in on the target via onboard radar and a guidance and control system, for an HTK intercept. Range safety requirements dictate the incorporation of a Flight Termination System (FTS) for each missile. The FTS command receiver each used one unique 3-tone command destruct sequence.

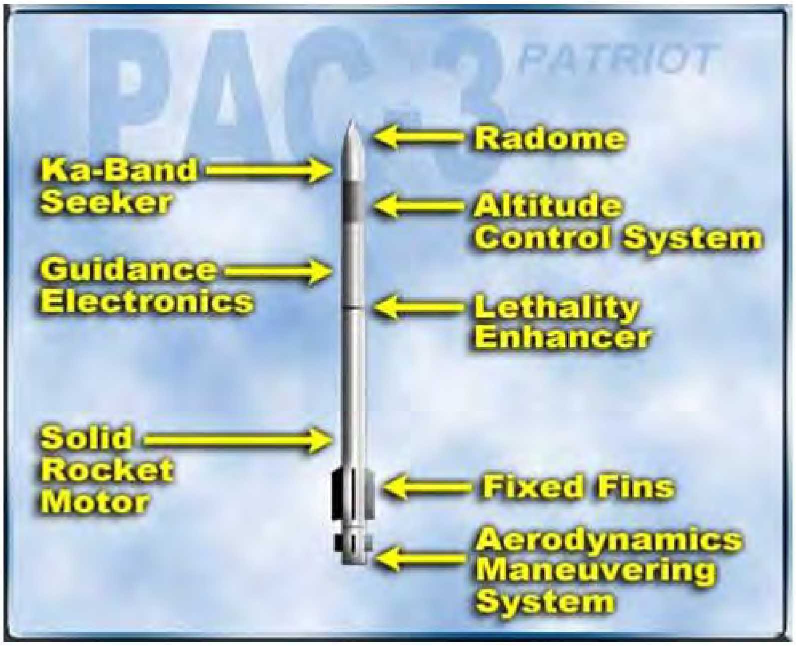

Figure 8. PAC-3 Missile Major Subsections (from *Operations requirements No. 08920: Patriot*, 2011, p. 3)

The Patriot guided missile has four clipped-deltas with an all-movable tail propellant rocket motor. The missile is 531.52 cm (209.26 in.) in length, with a body diameter of 40.82 cm (16.07 in.) and a total fin span of 86.87 cm (34.20 in). The missile is rust-red color with two white cable conduits running the length of the missile at 180 degrees apart.

The radome assembly consists of a ceramic shell with slip-cast fused silica, a metal tip, and a glass-reinforced plastic base ring. The radome forms the major portion of an aerodynamic nose shape and serves as an RF window for the guidance seeker.

The Patriot missile warhead section contains a live warhead with a safety and arming device (S&A) mounted to its base plate. The S&A, designated M143, provides safety by inhibiting detonation of the warhead until the missile is a safe distance from the launcher.

The warhead firing circuit can be activated by signals from the fuse, by a command destruct signal from the modular digital airborne guidance section (MDAGS), or by a self-destruct circuit. The self-destruct circuit can activate the S&A if there is a loss of on-board missile power, loss of a series of uplink messages, or specific malfunction in the missile. Command destruct from the MDAGS results from an uplink message sent by the radar.

WSMR provides the following test support: optics (tracking and non-tracking), telemetry, radar, meteorology, range control, and communications. The data products provided by WSMR personnel are shown in Table 3.

PAC 3 Data Products	
Raw Data	Radar Tapes (Missile, Aircraft, Target)
	Telemetry Tapes
	Cinetheodolite Media
	Telescope Media
	Non-Track Optical Data/Fixed Camera Media
In-Test Data	Trajectory Plots
	Trajectory Tapes
	Telemetry Plots
	Telemetry Tapes
Post-Test Data	Trajectory (Missile, Aircraft, Target)
	Miss Distance
	Telemetry
	Events or Time
	Geodetic Survey Computation
Frequencies	Telemetry (Missile)
	Radar, Fuze, Downlink (Missile)
Documentary and Aerial Photography	Stills
	Motion Picture
Recovery	Location
	Hardware
Recovery Aid	Radar Look Angles to Impact Point
	Radar Range to Impact Point
	Non-Track Optical Look Angles to Impact Point
	Telemetry Look Angle At Loss of Signal
Other Items	Test Results of Rocket Assembly and Checkout

Table 3. PAC 3 Data Products

G. ORGANIZATION

The organization of this thesis includes an Introduction (Chapter I), Historical Mission’s Business and Cost Impact (Chapter II), Current WSMR Business Process (Chapter III), Permanent Infrastructure (Chapter IV), Network Equipment (Chapter V), Summary and Recommendations (Chapter VI), and List of References.

II. HISTORICAL MISSION’S BUSINESS AND COST IMPACT

In this chapter, the WSMR customer’s voice will be portrayed. Data will be gathered on previously completed missions to find out if customers are completely satisfied with the service and products they are currently receiving from WSMR or if there is an existing problem with the way WSMR currently conducts business. No human subject research will be conducted but an analysis of existing data will be conducted.

A. CUSTOMER SURVEYS

Customers are encouraged to provide feedback after executing a mission via a survey. The surveys, which cover a variety of subjects (e.g., cost, scheduling, and mission execution) are submitted directly from the customers to the WSMR Business Development Office (BDO). The WSMR BDO works directly under the WSMR Commander shown as the “Commander” in the center gray box in Figure 2. The WSMR BDO’s mission objective is to provide command level planning, business development, sustainability, marketing, strategic planning, and plans/operations tracking and coordination with team WSMR organizations. This survey communicates the positive and negative lessons that were learned, from the initial planning, conducting, and post-mission reporting of each scheduled event. Once customer surveys are received, the WSMR BDO office they are analyzed and distributed to the WSMR management team in the various directorates to make all of the organizational stakeholders aware of the issues, generate lessons learned, and recommend solutions for future events.

The WSTC customer survey form was formulated to enhance the customer survey high level metrics and address specific WSMR requirements. The customer survey’s goal is to improve WSMR customer services by establishing a straight-forward method for the customers to provide feedback concerning WSMR services and to task WSMR organizations to respond to customer criticisms with any needed improvements. WSMR BDO uses a customer survey automated tool website that is created and provided by WSMR’s headquarters, the Army Test and Evaluation Command (ATEC), to send, receive, store, and report customer surveys. The customer survey is composed of five main sections; test planning, test execution, test reports, cost estimate, and customer service. These five main sections require the customer to directly rate the service provided by WSMR support as one of the following: exceeded, met, or needs improvement. If one of the sections is marked as “needs improvement,” then the customer is requested to mark one or more of the specific areas needing improvement. The specific choices to select are listed in the needs improvement columns in Table 4.

<table>
<tr><th colspan="5">Sample of Five Main Sections within Customer Survey</th></tr>
<tr><th>Test Planning</th><th>Test Execution</th><th>Test Reports</th><th>Cost Estimate</th><th>Customer Service</th></tr>
<tr><td>Exceeded</td><td>Exceeded</td><td>Exceeded</td><td>Exceeded</td><td>Exceeded</td></tr>
<tr><td>Met</td><td>Met</td><td>Met</td><td>Met</td><td>Met</td></tr>
<tr><td>Needs Improvement
•Insufficient Detail
•Timeliness
•Communication/ Responsiveness
•Other—Specify</td><td>Needs Improvement
•Test Preparation and Setup
•Reschedule/delays
•Failed to follow plan
•Communication/ responsiveness
•Remedies to unanticipated issues
•Infrastructure
•Other—Specify</td><td>Needs Improvement
•Timeliness
•Data Quality
•Communication/ Responsiveness
•Report Quality
•Other—Specify</td><td>Needs Improvement
•Estimate
•Timely Budget/ Cost Data
•Budget/Cost Tracking
•Communication/ Responsiveness
•Other—Specify</td><td>Needs Improvement
•Communication/ Responsiveness
•Availability of Key Personnel
•Corrective Action Resolution
•Other—Specify</td></tr>
</table>

Table 4. Sample of Five Main Sections within Customer Survey

A total of 212 surveys were sent between FY10 and FY12 (FY10–80 surveys, FY11–63 surveys, and FY12–69surveys) to the various customers, with an average response rate of 52%. As shown in Figure 9, between FY10 and FY12 data showed that an average of 60% exceeded test planning, 78% exceeded test execution, 40% exceeded test reporting, 25% exceeded cost expectation, and 79% exceeded customer service. As shown in Figure 10, between FY10 and FY12 data showed that the an average of 34% met test planning, 16% met test execution, 54% met test reporting, 64% met cost expectation, and 18% met customer service. As shown in Figure 11, between FY10 and FY12 data showed that an average of 4% needed improvement in test planning, 4% needed improvement in test execution, less than 1% needed improvement in test reporting, 6% needed improvement in cost expectation, and 2% needed improvement in customer service. The results described above showed that between FY10 and FY12 there were 29 out of 112 customer surveys with negative feedback on test planning and 24 out of 112 customer surveys with negative feedback on cost expectation. These results for the first five main sections of customer surveys between FY 10 and FY 12 timeframe pointed towards two main areas of concern: test planning (which accounted for test scheduling) and cost expectation.

Figure 9. Customer Survey Exceeded Ratings for FY10 through FY12

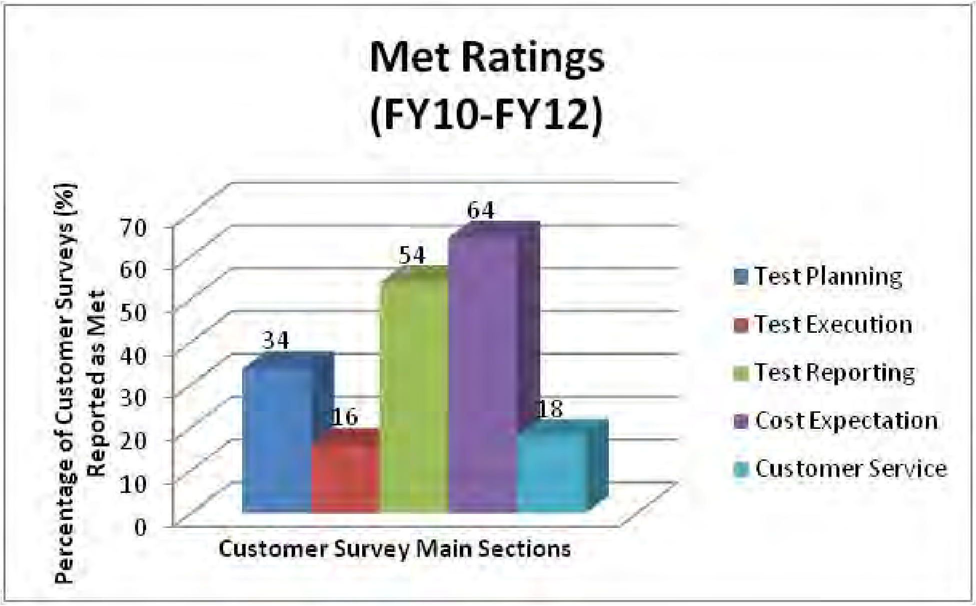

Figure 10. Customer Survey Met Ratings for FY10 through FY12

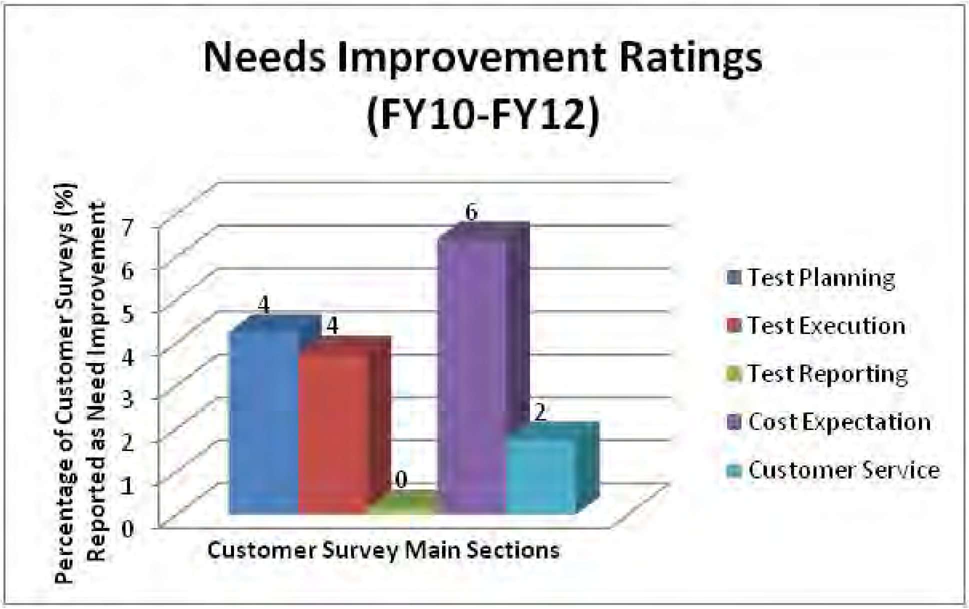

Figure 11. Customer Survey Need Improvement Ratings for FY10 through FY12

The customer survey also consists of five additional specific questions that require customers to answer with a direct yes or no type answer. Also, these questions provide space for customers to provide specific comments as to why they choose to mark their answer as yes or no. The five specific questions included in the customer survey are as follows:

- Overall were you satisfied with the test scheduling process?
- Was your test scheduled within a week of your requested timeframe?
- Were all of your instrumentation requirements met?
- Was your test data provided in time to meet critical milestones?
- Would you use our services again?

The pie charts in Figures 12, 13, and 14 show the feedback from customers from just the first two questions provided above. According to these charts, many customers have consistently been unsatisfied with the scheduling of their missions. On average, between fiscal year 2010 and fiscal year 2012, about 7% of the surveys reported dissatisfaction with the test scheduling process and about 8% of the surveys reported that their test was not scheduled within a week of their requested time frame. WSMR has already begun working on correcting these problems.

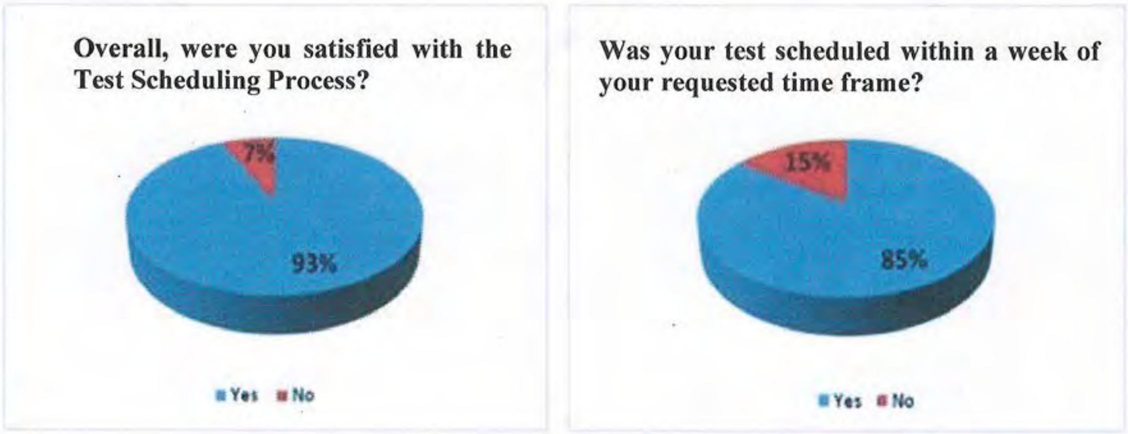

Figure 12. WSTC Customer Survey Specific Questions—FY10

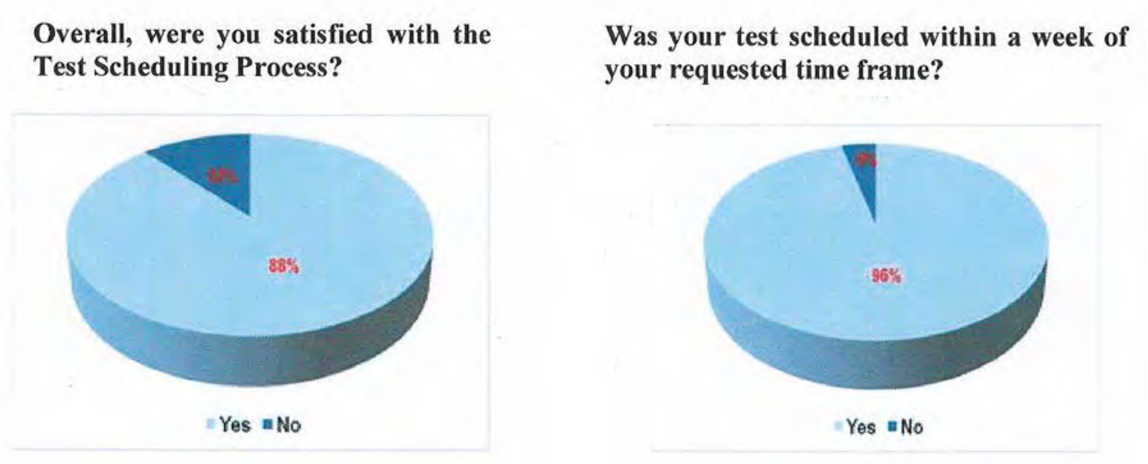

Figure 13. WSTC Customer Survey Specific Questions—FY11

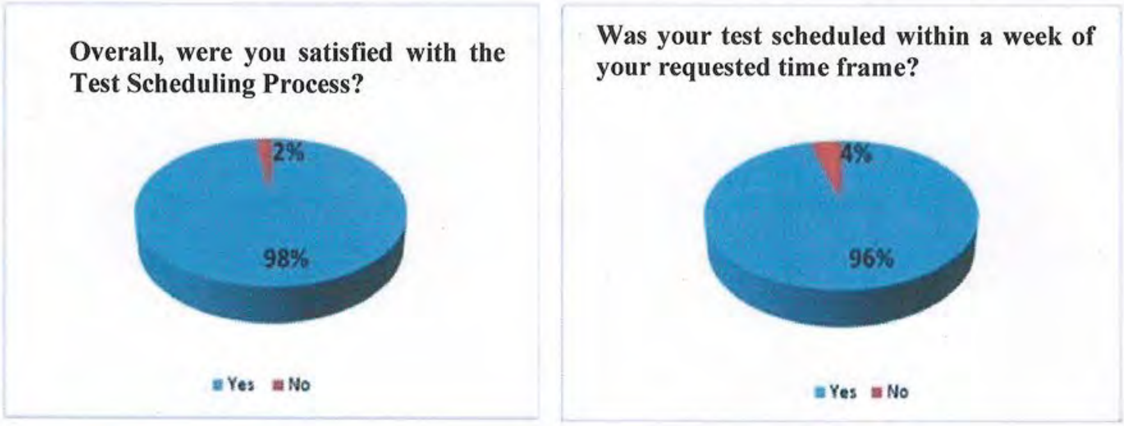

Figure 14. WSTC Customer Survey Specific Questions—FY12

WSMR’s ultimate goal is to become the benchmark for quality, cost-control, transparency, delivery, and breadth of services by providing the most efficient, convenient, timely, and accurate range testing for its customers (*Strategic Plan*, 2012). To accomplish this goal, energy was focused on solving these existing negative issues that were brought to light by the surveys, to include understanding which area of the overall process is responsible for increasing the cost and preventing projects from meeting critically scheduled milestones.

B. COST BREAKDOWN ANALYSIS

As stated earlier, this research focused on three programs in order to conduct an actual cost breakdown analysis: JAGM, GMLRS and PAC-3. WSMR projects are normally broken down into a series of different test phases. Not all programs go through the same test phases; it all depends on the objectives that each project is required to meet. Sometimes, testing is limited by availability of funds for each project and how much testing they can afford. Some of the most common test phases, or tasks, are planning support, pre-test activities, captive flight tests (CFT), hot missions, firing readiness tests (FRC), ground checks (G/Cs), pad integration, tearing down of equipment setup, data reduction, and post-test support.

In order to find out which test phase might have been the most costly for a particular project, data was collected on each of the three missions. As shown in Figures 15, 16, and 17, the different test phases for each mission were individualized with their costs. Comparisons were made on each project's test phase to disclose estimated costs vs. actual costs. Data revealed that the actual cost to support certain test phases greatly exceeded the cost estimates. For example, as shown in Table 5, the JAGM mission had an overall cost increase of 32% between the estimated cost and the actual cost, with the biggest increase of 389% occurring during the pad integration phase. Table 6 shows that the GMLRS mission had a cost increase of 16% for the actual flight test itself and 11% for the pre-test activities. Table 7 shows that the PAC-3 mission had an increase of 6% between estimated and actual cost, but its greatest impact of cost increase was reflected on the mission's ground checks, which had an increase of 33% between the estimated cost and actual cost. The data provided in Figures 15, 16, and 17 clearly identify the problems with projects exceeding cost during certain test phases, particularly during the planning phases. This data is consistent with the data from the customer surveys which reports negative feedback on the inability to meet estimated project costs and schedule. In order to further isolate the costs associated with each of these missions, the next section concentrated on researching and finding out the different costs associated with each of the test phases and the type of personnel providing this support. Each of the test phases is supported by different organizational groups within the WSMR test team. They include a mixture of contractors and civilians, as well as subject matter experts, who specialize in a variety of technical fields. These personnel assist in the areas of non-track optics, radar, and telemetry. In order to find out which particular personnel group is responsible for increasing the cost while performing a particular test phase, cost breakdowns and analyses were conducted for each of the three missions and for each of the more costly test phases, which in each instance was discovered to be the planning phase.

JAGM Estimated Cost vs. Actual Cost		
Row Labels	**Estimated Cost**	**Total Actual Cost**
Operation B (CFT and HOT Mission)	$304,476	$355,458
Operation XA-1 (Pad Integration)	$7,270	$64,649
Post Test Support	$17,908	$15,582
Grand Total	**$329,654**	**$435,690**

Table 5. JAGM Estimated Cost vs. Actual Cost

GMLRS Estimated Cost vs. Actual Cost		
Row Labels	**Estimated Cost**	**Actual Cost**
Planning	$27,603	$4,616
Pre-Test Activities	$128,233	$142,336
FRC	$49,182	$50,785
Flight Test	$137,936	$159,361
Tear Down, Impact Area Activities, Data Reduction	$135,056	$71,371
Grand Total	**$478,010**	**$428,469**

Table 6. GMLRS Estimated Cost vs. Actual Cost

PAC-3 Estimated Cost vs. Actual Cost		
Row Labels	**Estimated Cost**	**Actual Cost**
P7–4 FRC (combined with P7–3)	$150,467	$146,676
P7–4 G/Cs	$24,863	$54,105
P7–4 Hot	$217,205	$251,960
P7–4 OR Processing	$28,300	$12,999
P7–4 Post Mission	$63,723	$1,471
P7–4 Pre-Mission	$186,090	$248,252
P7–4 Test Doc Preparation	$2,380	$0
Grand Total	**$673,028**	**$715,463**

Table 7. PAC-3 Estimated vs. Actual Cost

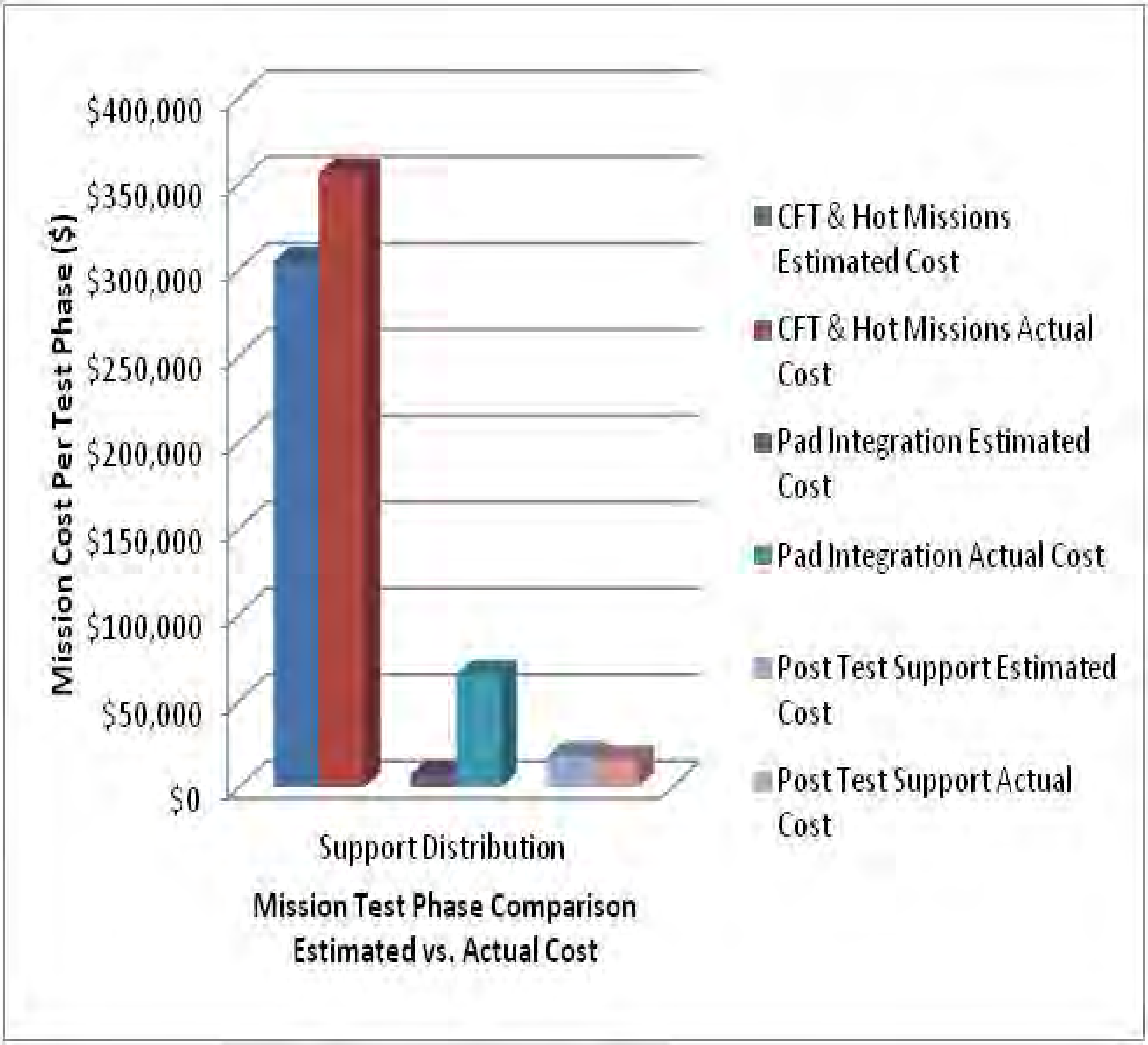

Figure 15. JAGM LM F2A Cost Breakdown

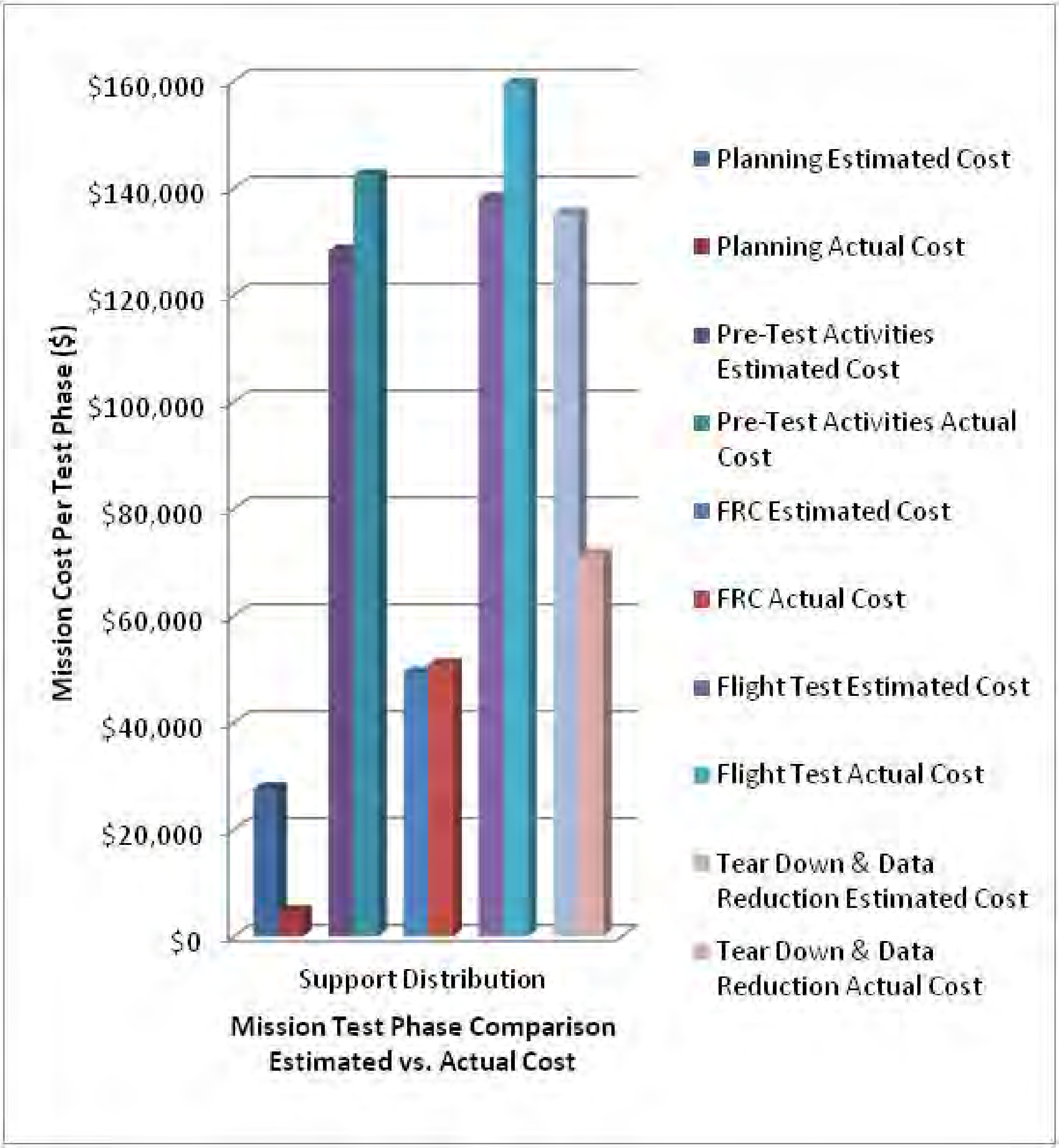

Figure 16. GMLRS UPVT-9 Cost Breakdown

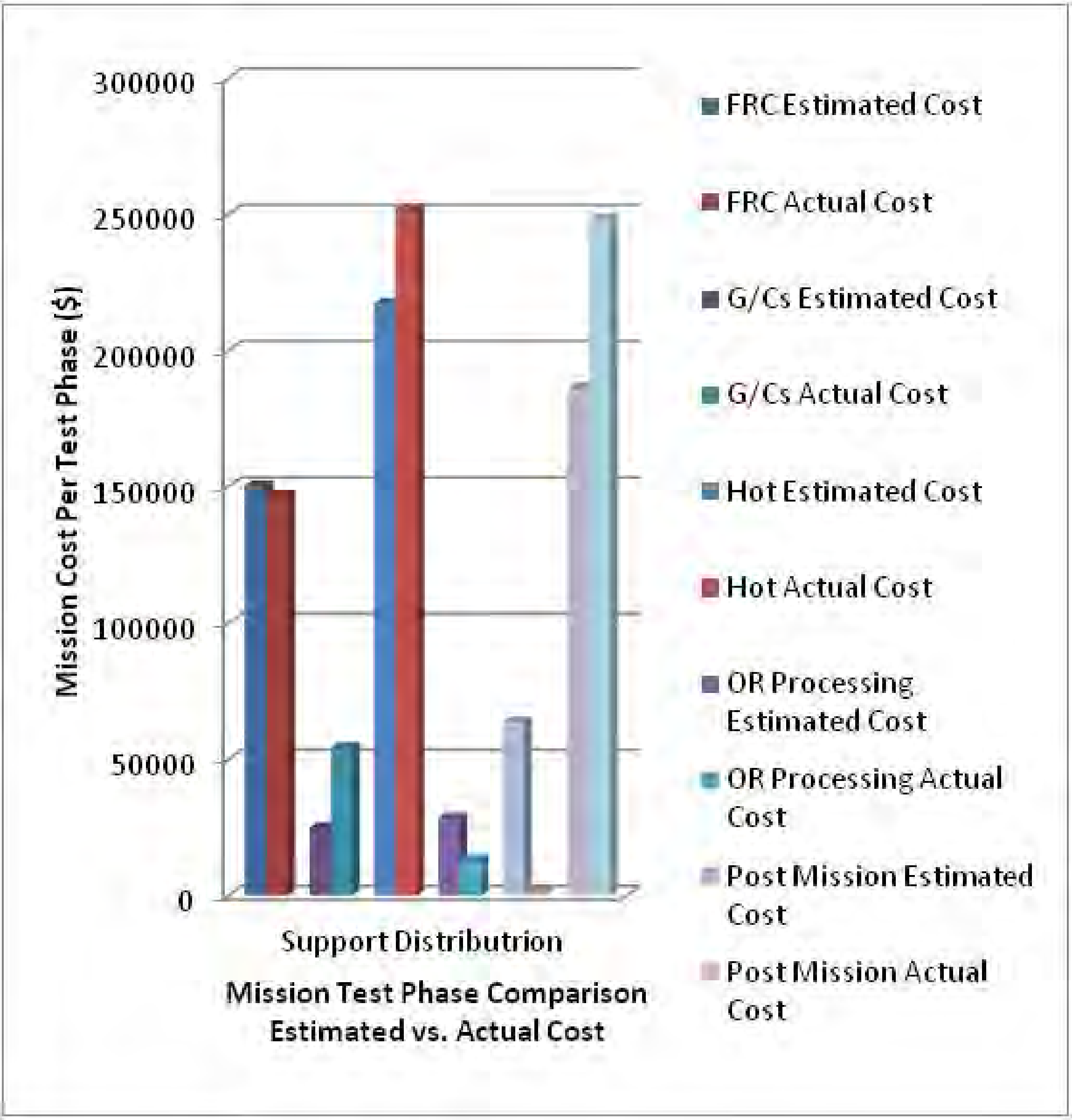

Figure 17. PAC-3 vs. PAAT P7–4 Cost Breakdown

1. JAGM Mission Cost Report

As detailed in Figure 15 in the previous section, the JAGM mission consisted of primarily CFT and hot missions, pad integration, and post-test support test phases. The support for these particular test phases was provided by RO, which consisted mainly of optics branch, IM real-time branch, MT manned tactical branch and MT warhead branch. All of these support groups worked as a team to execute these test phases. Table 8 provides a breakdown of the mission cost for each of the test phases and these specific support groups. During the CFT and hot mission test phase, the RO optics branch cost came out to $109,115, which was 65.7% of its overall cost of $166,036 for this specific test phase.

JAGM Breakdown Cost per Support Group and Test Phase

Row Labels	Overall Total Cost
Operation B (CFT and HOT Mission)	**$ 166,036**
IM Data Management Branch	$ 4,111
MT Warhead Test Branch	$ 1,062
RO Optics Branch	$ 109,115
RO Radar Branch	$ 15,184
RO Telemetry Branch	$ 36,564
Operation XA-1 (Pad Integration)	**$ 18,249**
MT Warhead Test Branch	$ 2,126
RO Optics Branch	$ 4,778
RO Telemetry Branch	$ 11,345
Post Test Support	**$ 15,582**
IM Data Management Branch	$ 15,582

Table 8. JAGM Breakdown Cost Per Support Group and Test Phase

The overall cost to support the JAGM mission, per each support group, is provided in Figure 18. The range operations (RO) optics branch was by far the most expensive support group with an overall cost of approximately $113,893 (i.e., $109,115 + $4,778). This cost amounts to approximately 26% of the overall JAGM cost of $435,690 (overall JAGM cost breakdown provided in Table 5).

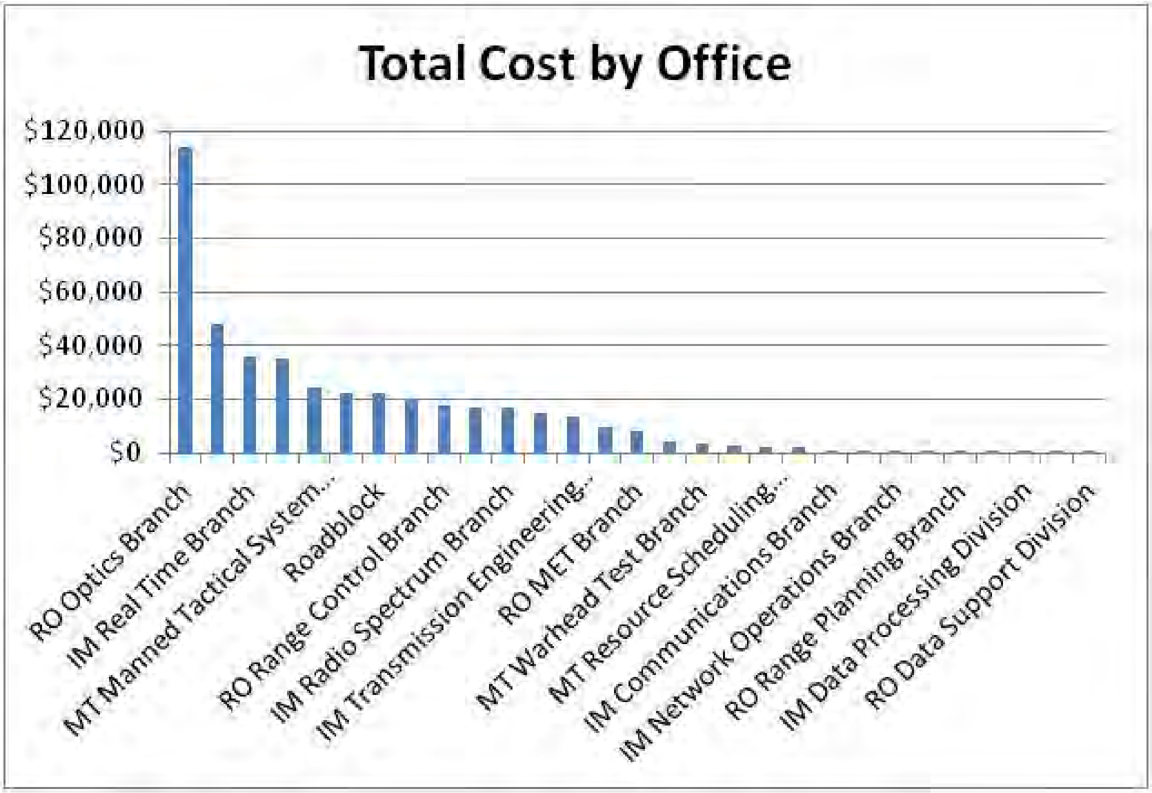

Figure 18. JAGM Total Cost by Support Group

2. GMLRS Mission Cost Report

The GMLRS mission consisted of a planning phase, pre-test activities, FRC, flight test, and tear-down & data reduction phases. Some of the main WSMR support groups that assisted with this mission were the RO optics branch, RO telemetry branch, MT warhead test branch, RO data reduction branch and MT manned tactical branch.

Again, all of these support groups worked together as a team to execute each of the test phases. Table 9 provides a breakdown of the mission cost for each of the main test phases and the specific support group. The RO optics branch came out with the highest cost after supporting the following test phases: pre-test activities at $35,452 (56% of the total cost); flight test at $48,600 (46% of the total cost); and planning phase at $1.029 (64.72% of the total cost). As previously seen from the JAGM cost breakdown, the RO optics branch came out once again as the most costly support branch overall at $89,513 (i.e., $35,452 + $4,432 + 48,600 + $1,029) for the GMLRS mission, as shown in the cost breakdown per support group in Figure 19. This cost amounts to approximately 21% of the overall GMLRS cost of $428,469 (overall JAGM cost breakdown provided in Table 6).

GMLRS Breakdown Cost per Support Group and Test Phase

Row Labels	Overall Total Cost
Tear Down, Impact Area Activities, Data Reduction	**$ 24,350**
MT Warhead Test Branch	$ 8,934
RO Data Reduction Branch	$ 15,416
RO Optics Branch	$—
RO Telemetry Branch	$—
Pre-Test Activities	**$ 63,365**
MT Warhead Test Branch	$ 23,450
RO Data Reduction Branch	$ 297
RO Optics Branch	$ 35,452
RO Radar Branch	$ 3,444
RO Telemetry Branch	$ 722
FRC	**$ 27,849**
MT Warhead Test Branch	$—
RO Data Reduction Branch	$ 4,266
RO Optics Branch	$ 4,432
RO Radar Branch	$ 1,081
RO Telemetry Branch	$ 18,070
Flight Test	**$ 105,121**
MT Warhead Test Branch	$ 2,853
RO Data Reduction Branch	$ 26,662
RO Optics Branch	$ 48,600
RO Radar Branch	$ 9,619
RO Telemetry Branch	$ 17,387
Planning	**$ 1,590**
MT Warhead Test Branch	$—
RO Optics Branch	$ 1,029
RO Telemetry Branch	$ 560

Table 9. GMLRS Breakdown Cost Per Support Group and Test Phase

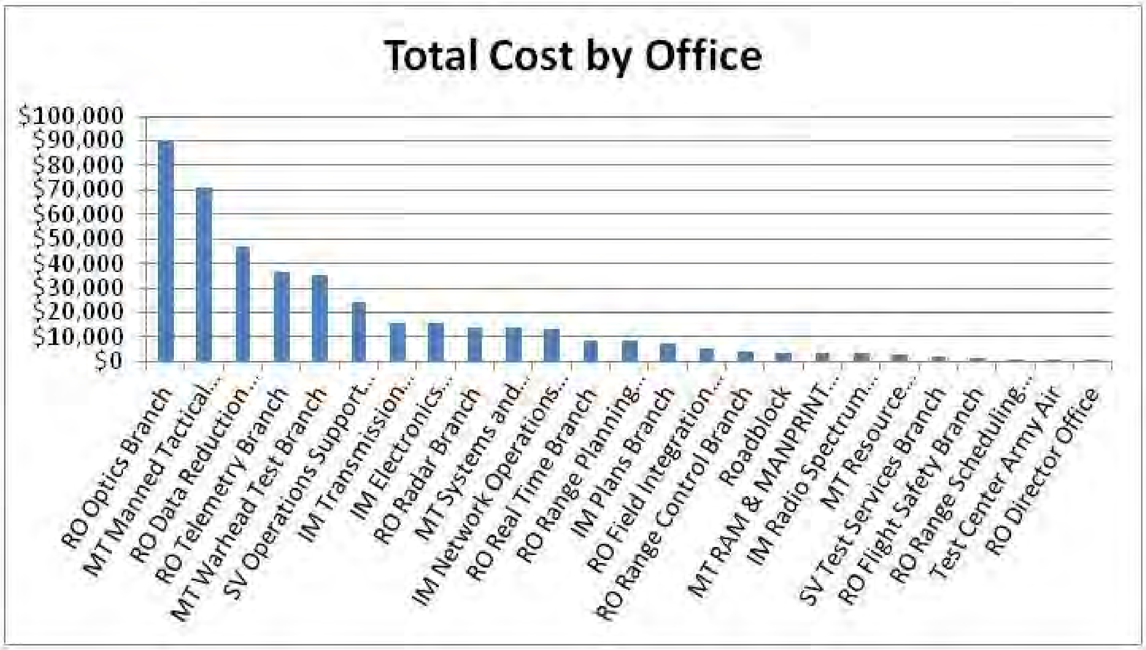

Figure 19. GMLRS Total Cost by Support Group

3. PAC 3 Mission Cost Report

The PAC-3 mission consisted of an FRC, ground checks, hot mission, OR processing, pre-mission and post-mission test phases. Some of the main WSMR support groups that assisted with this mission were RO optics branch, roadblocks (e.g., security guard support), RO telemetry branch, IM transmission branch, and RO radar branch. Again, all of these support groups worked together as a team to execute each of the test phases. Table 10 provides a breakdown of the mission cost for each test phase and the specific support groups mentioned above. The RO optics branch came out with the highest cost after supporting the following test phases: FRC at $39,490 (41% of the total cost); ground checks at $32,100 (99% of the total cost); hot mission at $61,759 (48% of the total cost); OR processing at $6,574 (79% of the total cost); and pre-mission at $84,140 (88% of the total cost).

Once again, on this third mission, the RO optics branch came out as the most costly support branch overall at $224,064 (i.e., $39,490 + $32,100 + 61,759 + $6,574 + $84,140), as shown in the cost breakdown per support group in Figure 20. This cost amounts to approximately 31.3% of the overall PAC-3 cost of $715,462 (overall PAC-3 cost breakdown provided in Table 7).

PAC-3 Breakdown Cost per Support Group & Test Phase

Row Labels	**Overall Total Cost**
P7–4 FRC (combined with P7–3)	**$95,353**
RO Data Reduction Branch	$11,040
RO Optics Branch	$39,490
RO Radar Branch	$18,068
RO Telemetry Branch	$26,754
P7–4 G/Cs	**$32,303**
RO Data Reduction Branch	$66
RO Optics Branch	$32,100
RO Telemetry Branch	$137
P7–4 Hot	**$128,530**
RO Data Reduction Branch	$25,487
RO Optics Branch	$61,759
RO Radar Branch	$15,513
RO Telemetry Branch	$25,770
P7–4 OR Processing	**$8,325**
RO Data Reduction Branch	$847
RO Optics Branch	$6,574
RO Radar Branch	$904
P7–4 Post Mission	**$281**
RO Data Reduction Branch	$0
RO Radar Branch	$281
RO Telemetry Branch	$0
P7–4 Pre-Mission	**$95,375**
RO Data Reduction Branch	$1,008
RO Optics Branch	$84,140
RO Radar Branch	$7,671
RO Telemetry Branch	$2,557
P7–4 Test Doc Preparation	**$0**
RO Telemetry Branch	$0

Table 10. PAC-3 Breakdown Cost Per Support Group & Test Phase

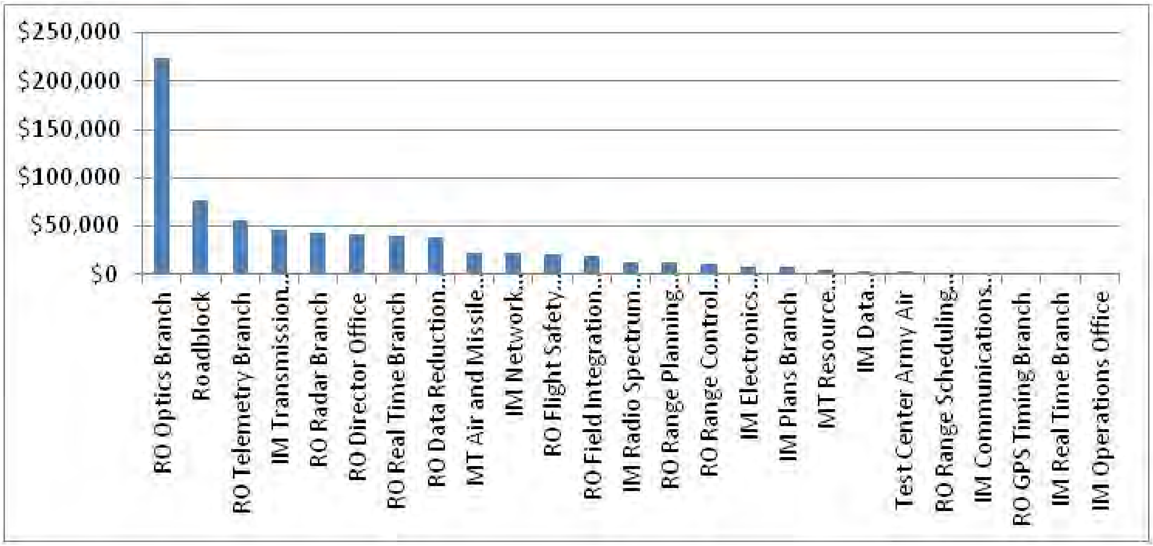

Figure 20. PAC-3 Total Cost by Support Group

C. MISSIONS BUSINESS AND COST IMPACT SUMMARY

Through customer surveys, it was speculated that there were existing issues at WSMR while providing test support. These main issues included poor performance on test planning (which account for test scheduling) and meeting customers cost expectations. The cost data collected for these three projects, JAGM, GMLRS, and PAC-3, later revealed and consistently demonstrated affirmatively that missions were greatly exceeding cost. This was done by directly comparing the estimated vs. actual costs for each of the three missions. This research then took these findings a step further to find out which specific test phases and support groups in the overall mission were responsible for the higher-than-normal cost. Each mission cost was broken down into test phases and personnel support groups to clearly identify the responsible parties driving the cost up. RO optics branch was clearly identified as the most costly, by far, for each of these three missions. In the next chapter, we will be taking a step back to completely define the WSMR business process, to include customers' submission of requirements, and WSMR's planning and executing a mission, and final reporting. This will allow us to identify possible root causes impacting missions schedule and cost and further analyze the data to recommend the best solutions to better support the customers.

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III. CURRENT WSMR BUSINESS PROCESS

A. HIGH LEVEL REQUIREMENTS PROCESS

The group clearly defined and documented the White Sands Test Center (WSTC) business process utilized to conducted business, to include the planning, coordination, execution, and reporting. The group then subsequently described in detail the method and structure used specifically by the Non-track Optics group for executing a mission. Organizational process structure refers to the division of labor as well as the patterns of coordination, communication, workflow, and formal power that direct coordination (*Organizational Behavior*, 2012, p. 234). The perceived issue with the Non-track Optics group is that their precise method of operation is not clearly defined or properly documented, which leads to confusion and inefficiency. Understanding how their process works is essential to ensuring the competitiveness of the organization (*Operations and supply chain management*, 2011, p. 112). WSMR's method of operation is a multistage process with multiple activities that are linked through flows. The group will determine the high level range requirements and the specific Non-track Optics flow charts.

New customers will contact the WSMR Business Development Office (BDO) when they are initially interested in testing. The BDO is the initial point-of-contact (POC) when researching options for any testing needs. The BDO will review the scope of work or requirements documents prepared by the customer and respond with a WSMR support proposal package and rough order of magnitude (ROM) estimate, based on the customer requirements. Once the proposal package and estimate meet the customer's satisfaction, BDO interfaces with the Project Review and Assignment Team (PRAT), which in turn, reviews the proposal and assigns a range sponsor organization. Approved range sponsor organizations are the Materiel Test Directorate (MT), the WSMR Air Force detachment, and the WSMR Navy detachment. Sponsor organizations are authorized by the Commanding General and committed to fulfilling program requirements. Figure 21 contains the initial process flow chart depicting a new customer coming to the range through the assignment of a test officer and range engineer.

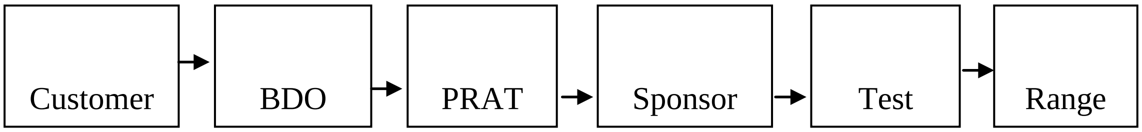

Figure 21. Initial Process Flow Chart

The sponsor organization has overall responsibility for coordinating test support activities necessary in planning and executing a test program. The sponsor organization then assigns a test officer (TO) to serve as the overall program manager for test support activities and is the customer's single point of contact. The TO is responsible for leading and managing a test team composed of engineering support, technical support, analytical support, mission operations, human factors engineering, safety, security, environmental, and logistical support. The TO works with the accounting and financial management analysts and the contract office representatives to manage and control program funds. The TO also provides, to the customer, information regarding WSMR capabilities, policies, and procedures.

Since all requirements are submitted to the range through the sponsor, the sponsor will confirm all customer support requirements and act on behalf of the customer to obtain WSMR services and in dealing with WSMR organizations. The TO represents the customer at the range scheduling meetings and also places job orders directly with various WSMR organizations to obtain mission support. The TO and customer will work together to create the operational requirements (OR) document, which is a detailed statement on the requirements for one, or more, specific mission operation. The OR provides a means for customers to submit their requirements to the range and ensures the range meets those requirements. Test planning and execution will be performed using the OR. These requirements from the customer, are coordinated with the range operations directorate (RO) range engineer through the TO. The range engineer (RE) coordinates range instrumentation and support based on detailed information provided in the OR. The RE assists the TO in all aspects of services that involve assets from RO and information management (IM) directorate. IM is commonly referred to as "commo." The IM directorate is tasked with transporting test data throughout the range over the existing fiber network. This includes coordination of early planning, all levels of documentation, data collection, validation of support plans, scheduling, and post-test data processing.

The range support organizations each develop a detailed support plan for each service request in the OR. The range support element then submits the support plan and cost estimate back to the RE in response to the requirements in the OR. Once the OR is approved and the test is on the range schedule, the test may then be conducted.

Figure 22 depicts the complete High Level Requirements Process map:

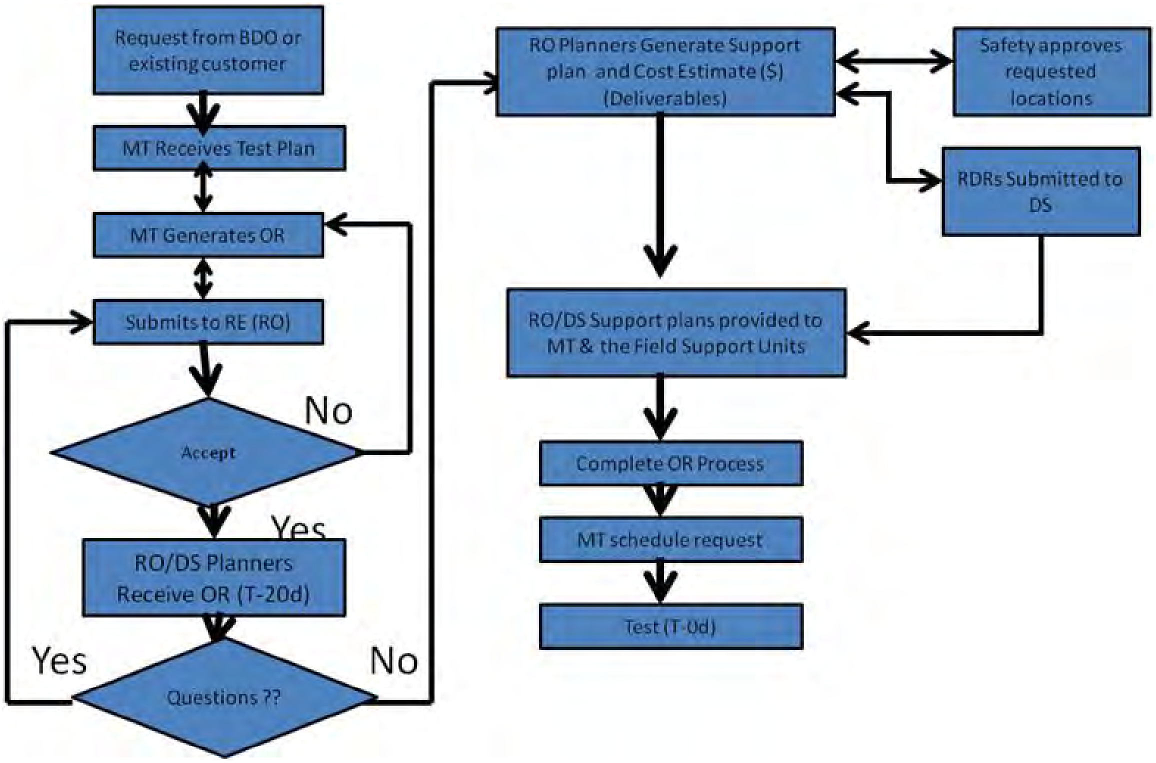

Figure 22. High Level Requirements Process map

B. SPECIFIC NON-TRACK OPTICS PLANNING PROCESS

The current Non-track Optics process can be summed up into four major processes: planning, scheduling, changes, and execution. The four processes come together to create the Non-track Optics organization. Planning begins when the TO generates an OR document for a specific test and submits it for review to the assigned RE. Once the RE is satisfied with the OR, it is accepted by the range and sent forth to the specific planners, in this case the optics planners. Optics planners process the OR and send specific non-track optics requirements to the Non-track Optics technicians. The Non-track Optics planners begin formulating instrumentation plans to meet the customers' requirements. The optics planners then generate support plans, uploads them into the optics database, and create an optics commo matrix to make sure commo supports their requirements. Non-track optics schedules are generated by the designated schedulers via optics support plans. The optics support plan details how the field technicians will support and execute each specific operation in the OR.

The scheduling process begins when the TO enters the customer's general requirements into the long range scheduling tool, called Test Resource Management System (TRMS). TRMS allows the TO to enter the basic test requirements, date, and timeline information. The "T-X" refers to the amount test-days that remain before test execution. For example, at T-60 days, the range de-conflict the forecast and "locks in" the daily test schedule for all hot missions. The range achieves this by conducting weekly scheduling meetings every Thursday to officially schedule missions out to four weeks. At T-7, final coding occurs; with concurrence from the optics scheduler, a range mission code is assigned to each test.

Customers are allowed to make last minute changes to their optics requirements through a "change request." This change request may come from the project through the TO, who may make the request via TRMS, or if on-site, by phone or e-mail. The field personnel may also contact the range engineer or optics planner with a change request. Once the optics planner is notified, he may accept the required changes or issue a data science limitation (DSL), which indicates the range will not be able to meet the customers' full requirements. The project may accept the DSL and proceed to execute the mission or the project can cancel if the DSL is going to adversely impact the mission. If the optics planner accepts the changes, he must modify the optics support plans and confirm the changes with the optics scheduler in order to execute the required changes.

Execution, which is the final step, occurs when the optics group sets up its instrumentation equipment in the field and collects video data during the hot mission. At the completion of the mission, the raw data is gathered and sent to data reduction group where it is analyzed and returned to the customer with the final data product. The complete Non-track Optics process can be summed up in the process chart in Figure 23.

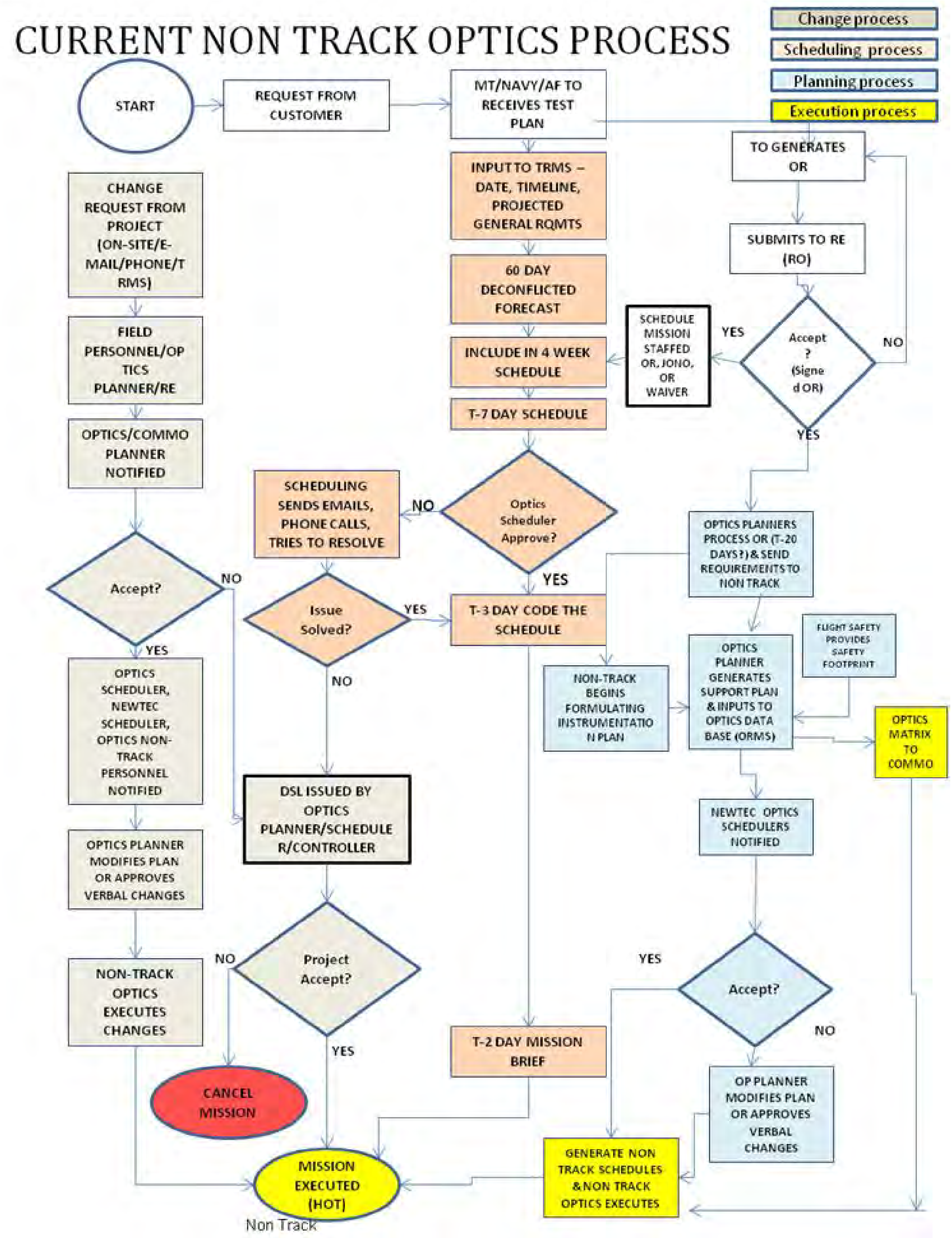

Figure 23. Current Non-Track Optics Process

C. PROBLEM IDENTIFICATION

WSMR Non-track Optics is currently unable to efficiently support customer requirements based on the costumer exit surveys. The support from Non-track Optics has transitioned from simpler, non-mobile, and film-based equipment at pre-established sites to a versatile, mobile, and digital system. The trade-off with this transition is that the newer systems require specialized skills, physically demanding labor, and time consuming set-up and tear-down procedures. Due to the complexity and extensive amount of time that it takes to set-up and tear-down these mobile systems, WSMR Non-track Optics is consistently exceeding their mission support cost estimates. Additionally, as a result of the significant amount of time to set-up and tear-down the Non-track Optics equipment, WSMR's scheduling office has a difficult time in scheduling mission support for other programs due to non-availability of equipment and manpower.

It was apparent from listening to the voice of our customers and from the post-test exit assessments that the Non-track Optics group was not measuring up to customer satisfaction in two main areas: cost and scheduling. The JAP members investigated and determined the critical root causes of the unsatisfactory support by communicating with the Non-track Optics subject matter experts (SME), reviewing post-tests after-action items, reading the lessons-learned reports, and reviewing optics data logs and troubleshooting calls. These negative issues were caused by numerous factors. A list of 30 root causes was compiled, to include:

- Network equipment failures: malfunctions within commo network equipment that supports optics test beds.
- Lack of permanent infrastructure: increases setup and complexity of the optics plan
- Computer interface security requirements: additional restraints levied on the field technicians to uphold information assurance directives.
- Lack of personnel: inefficient number of technicians to support numerous tests.
- Schedule changes: changes to the range schedule cause delays in setup, teardown, and turnaround time
- Lack of adequate advanced requirements: last minute changes to optics setup plan

- Lack of cameras: insufficient amount of equipment
- Travel time to sites: duration of time to travel to and from the test site and main post
- Lack of accurate info: insufficient coordination regarding range roadblocks and coordination with other range elements, such as communications, fuel, and generator groups
- Conflicting requirements: scheduling conflicts occur when setup for one test is scheduled while another program has scheduled hot mission support
- Enclosures/mounting hardware: need to manufacture specialized fixtures and camera enclosures for each test setup in order to protect cameras during impact
- Lack of redundancy: if the system or equipment go down, there is no backup plan
- Increasing data download times: digital equipment collects large quantities of data requiring increased time to download

The JAP team then created a cause and effect study, by ranking the issues from most important to least important, taking into consideration how negatively the causes impacted the missions, how frequently the issues occurred, and how easily the issues could be addressed. The causes were given a score 1–10, with the highest score of 10 being the most critical cause and the lowest score of 1 representing a less significant cause and impact. The cumulative score for each cause was then used to rank the issues. The results of this investigation are provided in Figure 24. The results verified main issues needing to be addressed by the Non-track Optics group: lack of manpower and camera equipment, network support equipment failures, and the lack of permanent infrastructure. The resulting issues to address are lack of manpower and camera equipment. These issues could be easily remedied by hiring additional personnel and buying supplementary camera equipment. However, due to the government’s restrictions on hiring and the greatly reduced funding, this JAP has determined the only available solution areas are network support equipment failures and the lack of permanent infrastructure.

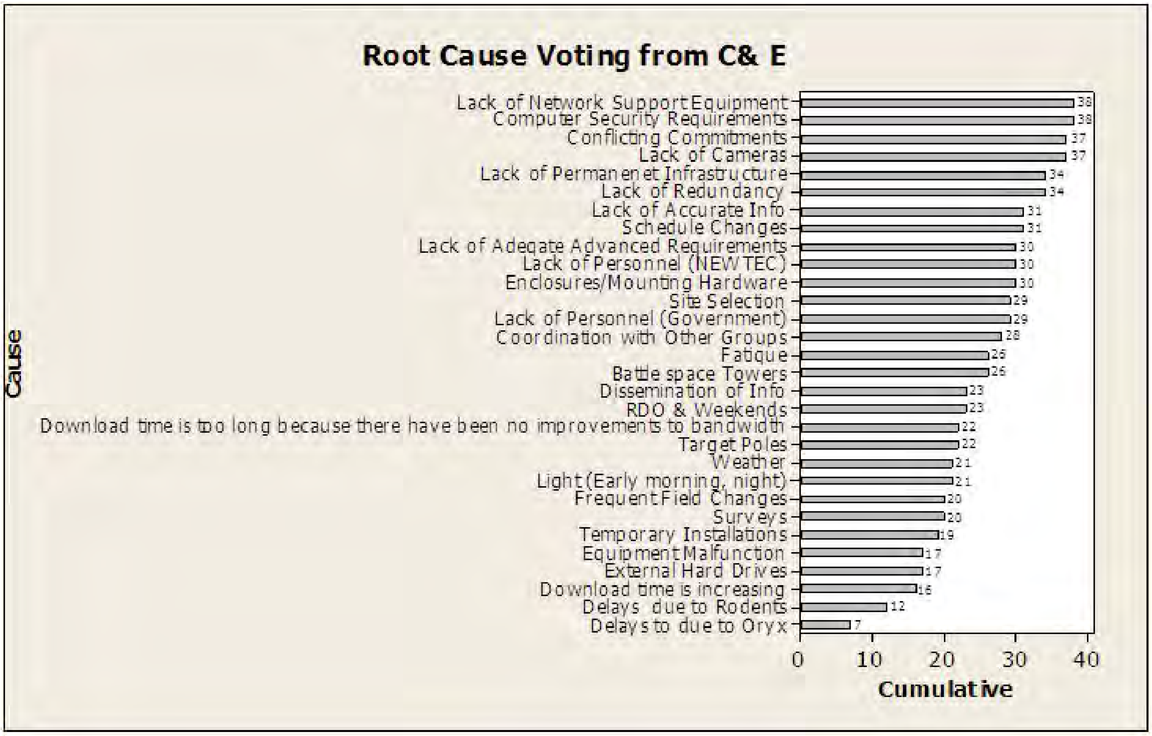

Figure 24. Root Cause Voting from Cause and Effect Study

Network support equipment failures lead to delays and increased troubleshooting time, costing the customer additional funds. Traditional network support equipment includes tactical local area network encryption (TACLANES), test support network (TSN) stacks, and microwaves. This equipment is used out in the field to collect and transport optics data during the live fire missions. TACLANES are communication security devices used to encrypt signals during transport of data. The TSN stacks are comprised of routers, switches, and fiber to ethernet converters that are used to access the WSMR test support network internet protocol (TSN-IP). The TSN-IP is a digital fiber optic network that supports transmission of analog and digital data throughout the range. Microwaves are used to transport video data via RF from the test beds out to a communication hub where it can then be placed onto the WSMR TSN-IP.

The lack of permanent infrastructure on the range means that the field technicians have an increased setup time due to the extra labor required preparing for each test. Lacking permanent infrastructure (i.e., underground cables, fixed pedestals, permanent TSN nodes and encryptors) increases the technician’s workload, stress, fatigue, and inability to support additional tests. If additional test sites were to contain permanent infrastructure resources, the field technicians would have reduced setup time, straightforward configurations, and a much greater likelihood of trouble-free missions. This would give the Non-track Optics group the capability to support additional customers throughout the year at a lower cost.

In the next chapter, the JAP members will further examine the methodology used in dealing with the network equipment failures and analyze how the failures affect the range missions and the customers. The JAP will also evaluate and define the issues associated with the lack of permanent infrastructure and then determine ways to mitigate these issues under the current test environment. If these two major concerns can be addressed, the Non-track Optics group could become more efficient and effective, and therefore provide major cost savings to the customer and ultimately the DoD.

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IV. PERMANENT INFRASTRUCTURE

A. METHODOLOGY

The lack of permanent infrastructure was identified as one of the key Non-track Optics issues. By infrastructure, we are referring to the basic equipment and structures that are needed for WSMR Non-track Optics to execute a mission. Currently, a non–permanent Non-track Optics basic set-up may require the following: trenching and placing field wire and fiber optic cable for control and communication with cameras, placing tripods according to specific requirements, construction of towers, installing target poles in alignment with camera angles, coordinating geodetic surveys (cameras and target poles), placing cameras on tripods, aligning microwaves for video distribution, and camera adjustments. Additionally, after conclusion of the mission, everything is removed and field wire is discarded.

As illustrated in the Fishbone Diagram, Non-track Optics site set-up in Figure 25, the Non-optic track site setup has four primary contributors to the labor issue which are as follows: lack of infrastructure, lack of equipment, improved communication (multiple organization required), and changing requirements.

The identified problem is that lack of infrastructure leads to increases in labor which in turn directly increases the cost. With this in mind, the JAP members used root cause analysis of permanent infrastructure to further quantify the need for permanent infrastructure, as well as explore the potential challenges and drawbacks associated with its implementation. First, we examined Non-track support processes and looked for ways to decrease costs, scheduling impacts. The most time consuming mission elements were then determined. Next, which mission element parts could be improved, as well as, the estimated cost and time savings to implement change was determined.

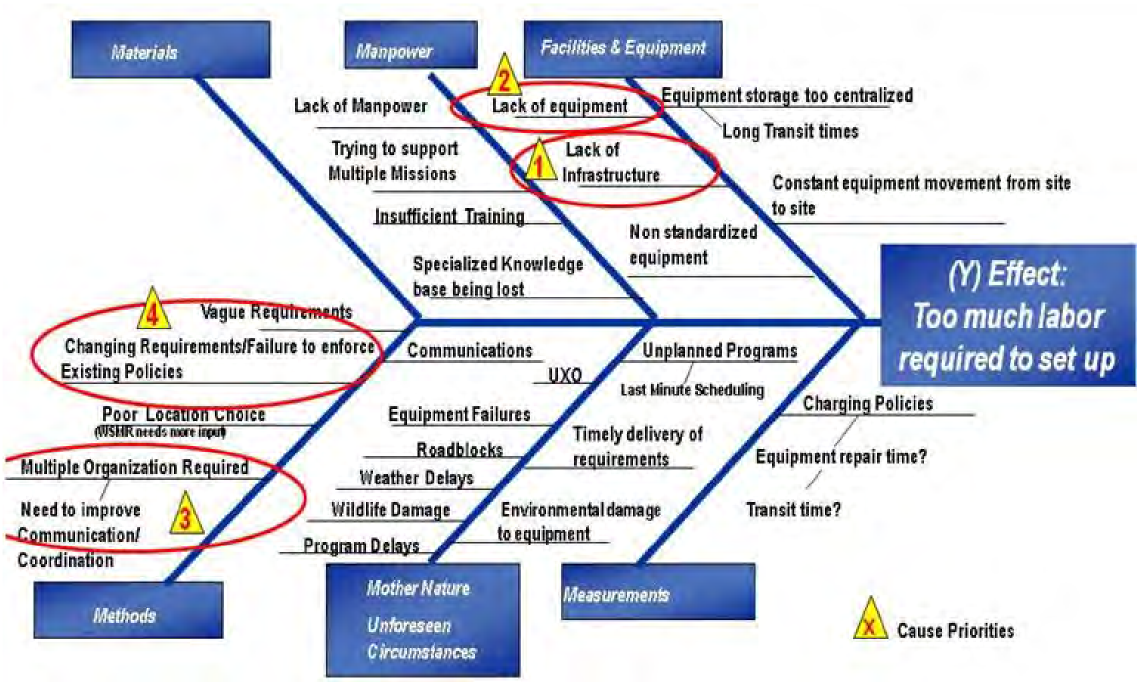
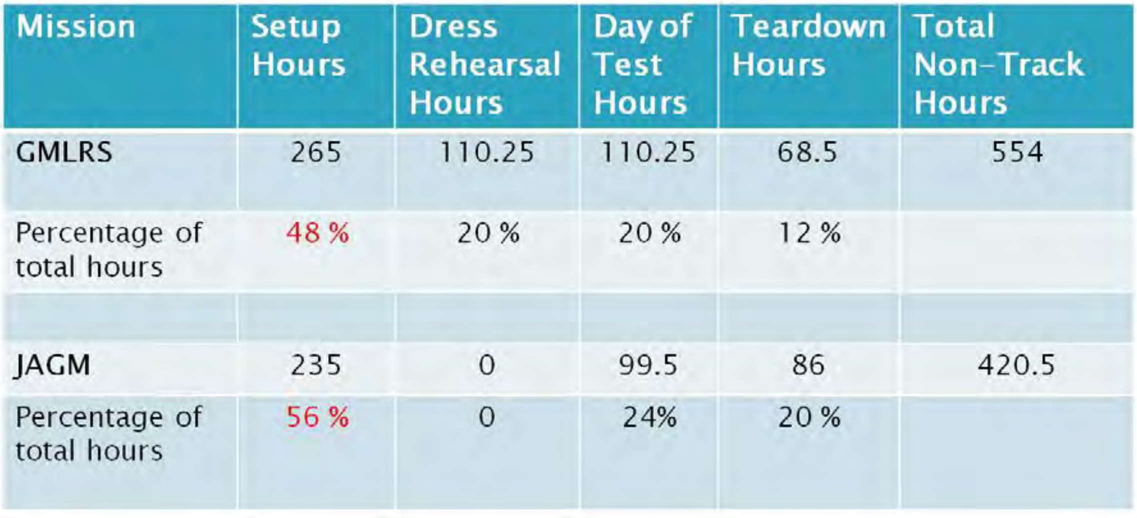


Figure 25. Fishbone Diagram Non-Track Optics Site Set-up

B. ANALYSIS

There are several non-track operations that contribute to the total time required to complete a mission. The complete mission set is comprised of set-up time, dress rehearsal before the day of testing, day of test, and the teardown after testing. A complete mission profile analysis is needed, to be able to identify which elements of the mission components are contributing most to the overall mission time. The JAP members used testing mission logs from the JAGM and GMLRS that provided the totals for setup hours, dress rehearsal hours, day of test hours, and teardown hours. Additionally we acquired the total sum of all of these non-track camera mission operation areas for non-fixed missions to calculate the total percentage of time for each mission elements. The total sums and percentages of non-track camera operations based on the JAGM and GMLRS representative missions were outlined in the mission profile analysis for non-track camera operations—Table 11.



Mission	Setup Hours	Dress Rehearsal Hours	Day of Test Hours	Teardown Hours	Total Non-Track Hours
GMLRS	265	110.25	110.25	68.5	554
Percentage of total hours	48 %	20 %	20 %	12 %	
JAGM	235	0	99.5	86	420.5
Percentage of total hours	56 %	0	24%	20 %	

Table 11. Mission Profile Analysis for Non-Track Camera Operations (based on two recent representative missions for JAGM and GMLRS)

These results outline the greatest percentage of time being spent on the setup component for the complete mission profile for both mission examples, which means that this was the key factor for reducing time for the complete mission set. These results, in examining the infrastructure as it relates to time and its impacts, translate directly into cost savings.

After it had been identified that the set-up is the key contributor for labor excesses within the complete mission set, the JAP members broke down the set-up mission component in to sub-components needed to complete the entire setup of a mission set. Using a variety of WSMR testing mission logs, the JAP members were able to construct a mission process road map that approximates the average time to execute a setup based on the approximate times to execute the sub components of the setup. Within the mission setup process map, we were also able to identify those components within the setup that could or could not be removed and those that could be reduced if we use a fixed site. (See Figure 26—optics non-track mission setup process map).

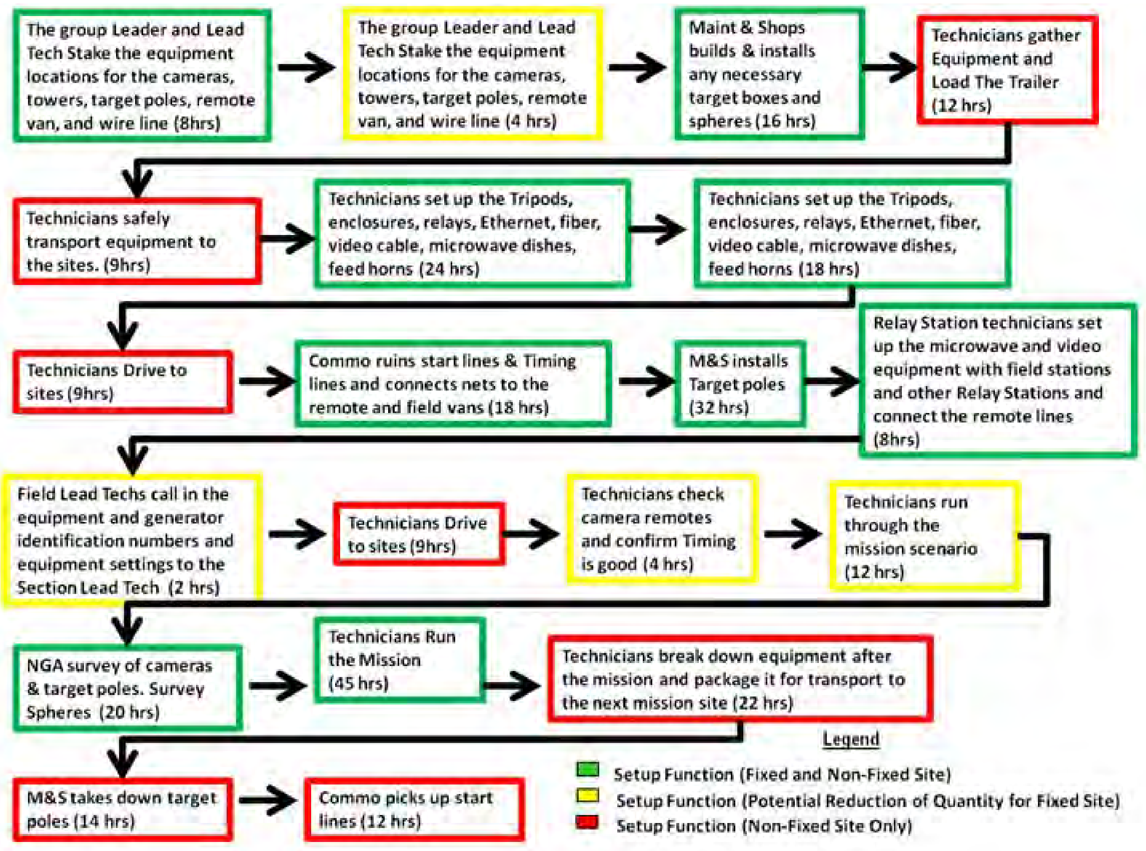


Figure 26. Optics Non-Track Mission Setup Process Map

As illustrated in Figure 26, the total approximate setup time would be 298 hours and by removing the setup functions highlighted above in red, that do not apply to a fixed site that can be reduced down to approximately 211 hours. Although those elements in yellow would reduce in quantity, currently there is not data available to quantify exactly what that amount would be. However, we can report that by utilizing fixed sites with permanent infrastructure the range can greatly reduce setup times. The total approximate range would be reduced from 298 to between 211 and 189 hours. At an approximate labor rate for contract support of $80.85 per man hours, just for the setup component alone, would provide a cost saving of approximately $8K per mission test. With an average of 8–10 missions per year, annual savings $64K–$110K/ year

The schedule impacts for an average 9 missions/year would that a total of 38 days of setup without infrastructure. That same average 9 missions/year would net a total average of approximately 19 days of setup. To put that in prospective, that 19 days setups savings could translate into overtime cost savings and/or more potential missions that could be executed.

Although a fixed site would save valuable time and money for the customer in the long run, acquiring the funding for this effort in this fiscal environment will be challenging. According to the military services, a significant portion of their budgets are consumed by infrastructure (i.e., buildings and permanent installations) including the necessary cost to operate them.

There are potential disadvantages for a permanent infrastructure, as it relates to flexibility. With a permanent infrastructure there would be less flexibility in selection of impact area locations and customers would have to select from predefined impact areas.

C. RESULTS

By examining both the non-permanent and the permanent infrastructures, the JAP team was able to further quantify the need for permanent infrastructure as well as explore the potential challenges and drawbacks associated with its implementation. It was determined by a root cause analysis that the set-up was identified as the key contributor for excessive labor within the complete mission set. The set-up component of the mission was further divided to sub-components in order to be able to determine which areas with the setup could be removed or improved. Through modifications to the process, the average time to execute a setup could potentially be reduced from 298 to 189 hours. Removing or modifying these key components would also reduce obstacles that could in turn reduce individual procedural problems inherent to each step. Additionally, a potential average cost savings of annual savings $64K–$110K/year, would be worthwhile for a group of program offices to do a cost sharing effort to support their ongoing programmatic efforts at WSMR Non-track Optic range.

After reviewing the advantages and disadvantages effects of permanent infrastructure, we have determined that the potential advantages far exceed the benefits. The JAP members will examine the second major concern with the Non-track Optics group (i.e., networking equipment) in the next chapter.

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V. NETWORK EQUIPMENT

A. METHODOLOGY

The information management directorate (IM) is organized into four divisions: Data Processing Division, Distributed Systems Division, Information Management Division and Programs/Projects Office. The IM Directorate operates and maintains the WSMR real-time and post-test computer systems. In addition, it provides real-time processing and display of both range instrumentation and telemetry data for range customers, as well as post-test analysis. The Distributed Systems Division uses distribution capabilities to support a mission to include the Inter-Range Control Center (IRCC), test support network, telephone and radio systems, and network communications. In addition, the range is equipped with hardware and software systems to analyze system performance and provide post test data reduction.

IM provides services to non-track optics when the support is required. IM personnel run the start lines and timing lines to provide connectivity to the optics remote and field vans. The optics technicians then check the camera remotes and confirm that the timing is reliable. The technicians then run through the mission to make sure the mission occurs as planned.

Network equipment is identified as a Non-track Optics issue. Network failures are occurring during Non-track Optics' operations, requiring frequent repairs or correction and having a broad effect on entire suites of optics equipment. Based on the analysis of failures, as shown on Figure 27, the average time of detecting and correcting failures is 35.6 hours. This, in turn, affects setup time, increases cost, interferes with evacuations and roadblocks, and decreases mission throughput. If the commo problem is solved, optics set-up time will cut customer costs, reducing schedule pressures that are the result of shifting evacuations, roadblocks, and other restrictions imposed by the range schedule. Reduction of these set-up times could also vastly increase mission throughput and reliability, resulting in higher reimbursable return, increased schedule availability and flexibility to the customer.

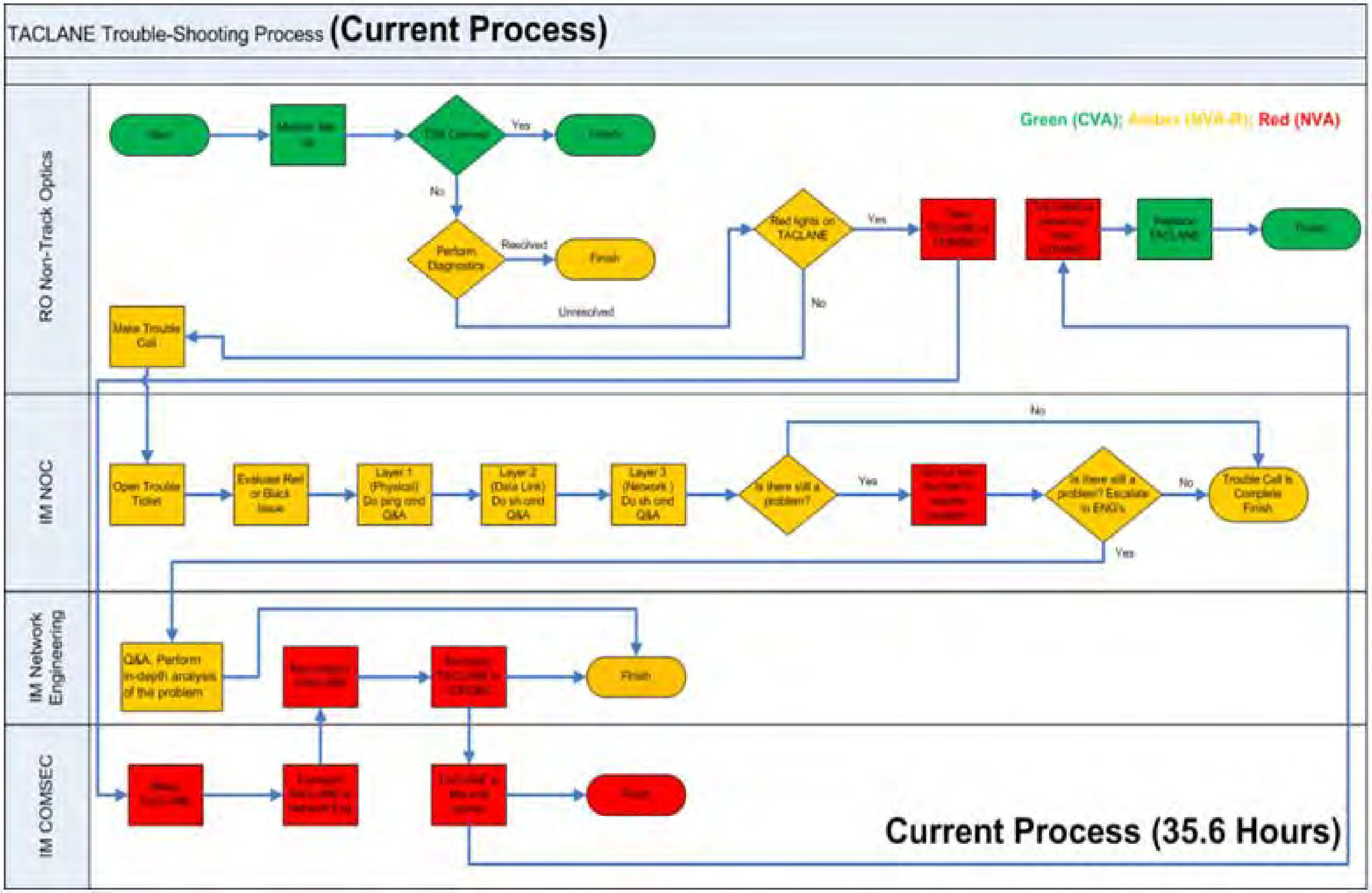


Figure 27. TACLANE Trouble-Shooting Process (Current Process)

B. ANALYSIS

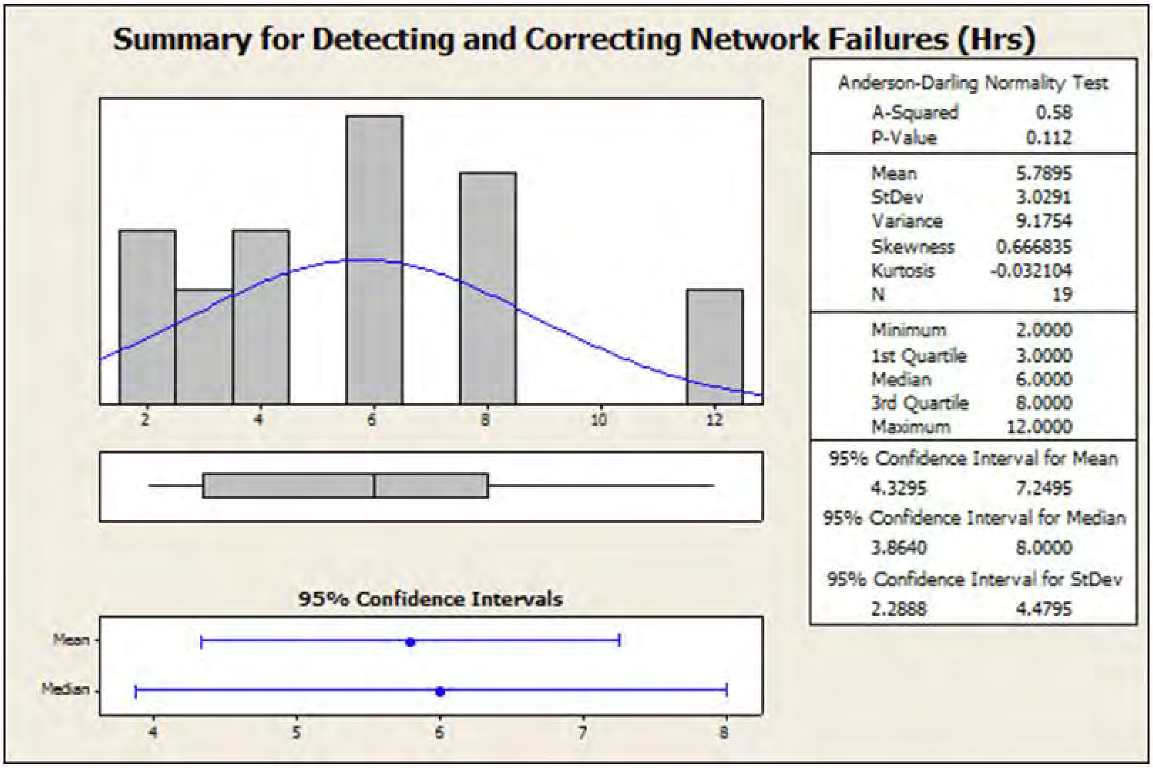
Based on the field log books that are carried out normally during missions at WSMR, data was collected and was compiled in Table 12. The data indicates the type of network problems and the number of hours spent correcting the problems.

Test Support Network (TSN) or Private Network	Network Problems	Hours spent on Connectivity Problems
P	Tried to extend TSN but could not	8
T&P	Problem with TSN Connection at Capital Peak. DS worked on connection at van and the cross-connect to Pole 616	6
P	Problem with TACLANES, then problems streaming video. Last-minute decision to rush TACLANES to Wingate, then they were not used anyway	48
P	BLDG 335 could not subscribe to the video	12
T	Could not multicast of receive multicast	3
P	NTDIS 2 network stack failed at T-20 minutes. All video streams lost. Still triggered cameras through wireless Ethernet link	4
P	NTDIS 2 network stack failed shortly before the first impact. Network stack was reset after first impact. No digital camera loss, only streaming video from one camera	3
T	Trouble connecting to TSN. DS cleaned fibers	2
T&P	NOC needed to configure a port on the MCC stack for TCM-930 Ethernet	6
T&P	The TACLANE failed. Pulled in a tracking shelter stack	108
T&P	Problem Connecting to DS van to get on TSN	8
T	TACLANE problem with visor TACLANE. Sent TACLANE in to COMSEC for software update. No problems with this TACLANE after this.	8
T	Problem Connecting to DS van to get on TSN	6
T&P	Trouble connecting to TSN through DS van	6
T&P	No FSTE at Site. Have to extend network to working TSN at Dog Site	4
T&P	Problem connecting to DS van	12
T	Private Network Problems with not enough bandwidth through the E100 TACLANEs	6
T&P	NTDIS network stack failed at T-2 minutes	2
T	Could not subscribe to multicast from VRF, NOC reconfigured stack and TACLANE to make it work. Added to router table	8

Table 12. Network Problems Raw Data

In order to conduct the analysis, the standard deviation formula (*Operations management for competitive advantage*, 2006, p. 348) was applied.

Figure 28 indicates the mean time is 5.7895 hours for Non-track Optics to detect and correct network failures. This analysis was derived from network problems during missions that personnel experienced, such as TSN connections at certain sites and video not being fed to the main control building. Other problems that personnel experienced were the inability to connect to the communications van in the field, tactical local area network encryption (better known as "TACLANE") issues, network stack issues, and TSN connection issues due to dirty fibers. TACLANE is a network encryption device developed to provide network communications security on internet protocol (IP) networks. Data was collected to determine the greatest network failure during Non-track Optics setup.



Anderson-Darling Normality Test	
A-Squared	0.58
P-Value	0.112
Mean	5.7895
StDev	3.0291
Variance	9.1754
Skewness	0.666835
Kurtosis	-0.032104
N	19
Minimum	2.0000
1st Quartile	3.0000
Median	6.0000
3rd Quartile	8.0000
Maximum	12.0000
95% Confidence Interval for Mean	
4.3295	7.2495
95% Confidence Interval for Median	
3.8640	8.0000
95% Confidence Interval for StDev	
2.2888	4.4795

Figure 28. Summary for Detecting and Correcting Network Failures

From the data in Figure 29 it was determined that TACLANE issues are the biggest defect. For the purposes of this section, emphasis will be placed on TACLANEs. The current process of trouble-shooting, using the TACLANE, consists of conducting the mission setup and performing all checks to see if the TSN is connected correctly. If the TSN is not connected, then diagnostics are performed. If the diagnostics are unresolved, the TACLANE is taken to COMSEC for repairs or the TACLANE is replaced. Depending on the situation and the condition of the TACLANE, this process can take as long as 35.6 hours to correct.

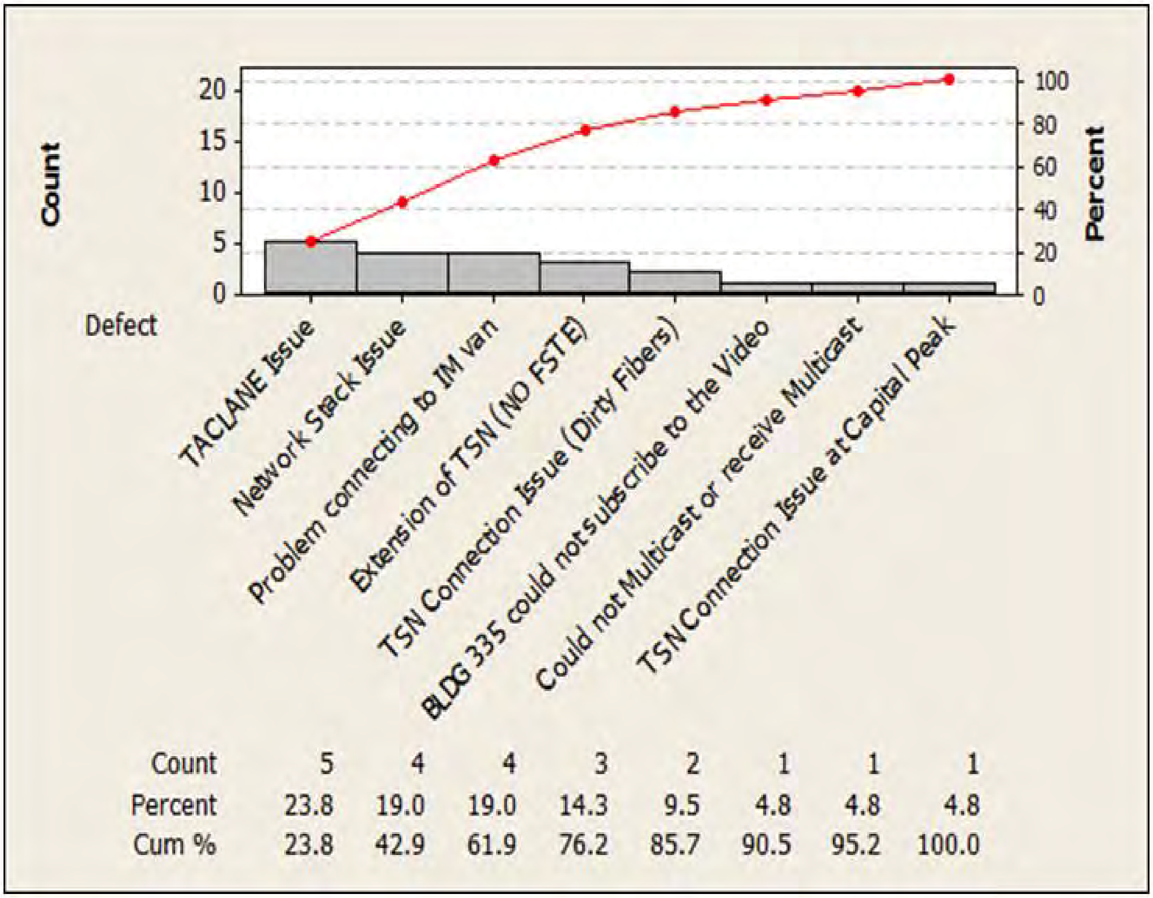


Figure 29. Classification of Network problems

C. RESULTS

The primary reason for network failure during Non-track Optics setup was the malfunction of TACLANE. In order to decrease the number of hours used to correct the problem, a potential solution is to order more TACLANEs. To determine if programs can share/reassign the TACLANEs, a review of existing inventory will be performed to determine what is needed for present and future mission requirements and offer a plan to budget for the purchase of TACLANEs over the next few years.

The future state process, shown in Figure 30, will eliminate the need to send the failed TACLANE to COMSEC for repair, therefore reducing the overall trouble-shooting process.

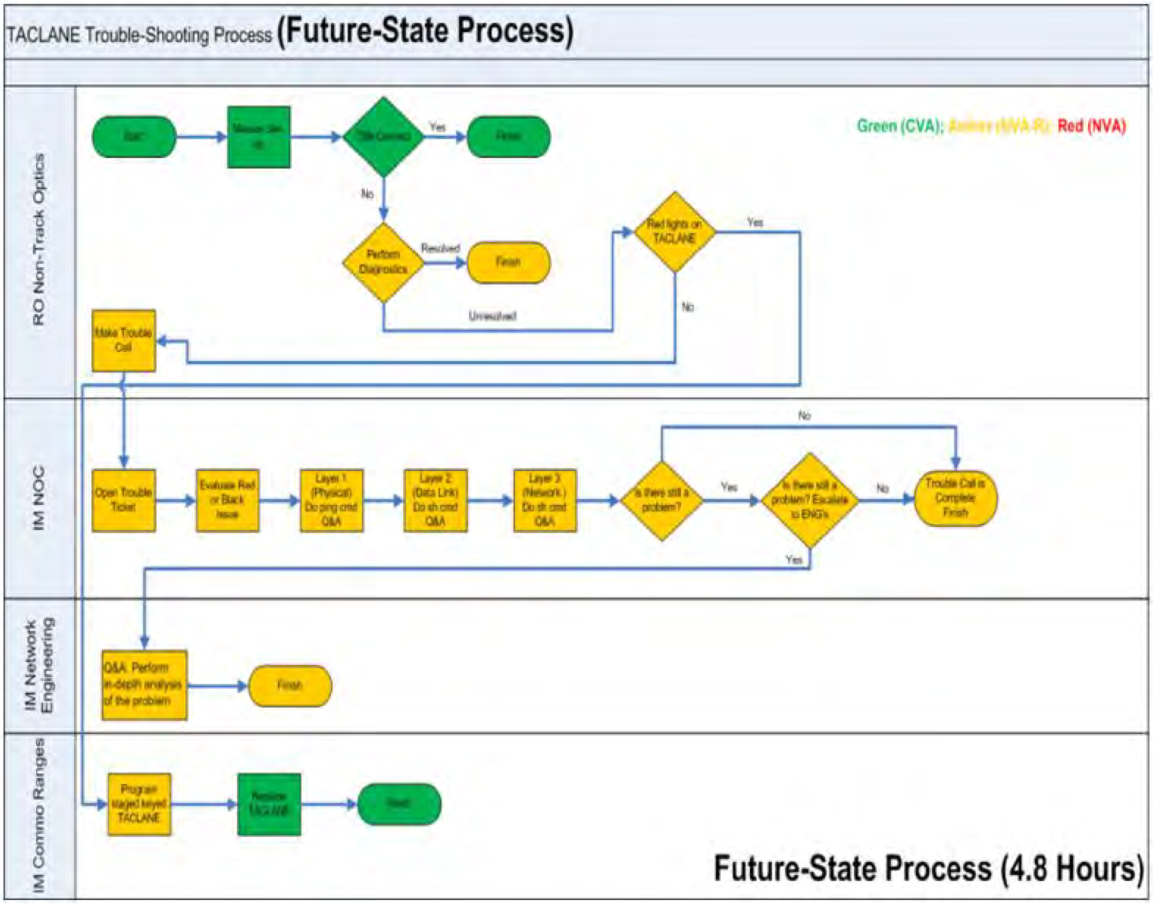


Figure 30. TACLANE Trouble-Shooting Process (Future-State Process)

VI. SUMMARY AND RECOMMENDATIONS

A. GENERAL CONCLUSIONS

According to WSMR customers, the WSMR business process did not meet the customer's expectations in test planning and cost. Through this Joint Applied Project (JAP), we first validated the customer survey proclamations and confirmed that missions were exceeding cost, specifically by the Non-track Optics group during the test planning phase. Second, this led to one of the main objectives of this JAP, which was to examine the WSMR Non-track Optics support processes and look for ways to decrease costs and scheduling impacts in order to increase throughput. The Non-track Optics process map had never been adequately defined and documented in the past. Third, after conducting a cause and effect study for the Non-track Optics organization, it clearly identified the lack of permanent infrastructure and consistent network failures as the top two root causes impacting mission schedules and cost. Fourth, data collected from historical missions showed that constructing a permanent infrastructure (as opposed to a mobile infrastructure) would reduce cost and time associated with the set-up and teardown. Fifth, data collected indicated that the reason for frequent network equipment failures was due to unreliable TACLANEs.

B. SUMMARY OF LESSONS LEARNED

A summary of the lessons learned from this JAP is listed below:

- The understanding of OR and support plan processes among MT, RO, and IM Directorates have been clarified.
- There is no standardization for developing and communicating changes to support plans.
- Non-track Optics process map had never been adequately defined and documented and hence, no performance data was readily available.
- The Non-track Optics equipment set-up is time intensive and complex
- The different functions of process owners have been clarified.
- Non-track Optics requirements were not clearly defined.

- Resource or manpower shortfalls are growing due to decreasing indirect support.
- Unexpected delays in schedule and/or higher priorities are interfering with project completion.
- Reliance on complex mobile systems requires manually intensive and lengthy set up and tear-down. The length and complexity of set up results in adverse schedule pressure at WSMR.
- Non-track Optics is perceived as being too expensive and difficult to schedule. This has been an ongoing concern due to the migration to digital technology.
- Network failures, specifically TACLANE failures, are occurring during Non-track Optics operations that have broad effect on entire suites of equipment. These failures require an average of 5.8 hours for detection and correction. The customer expects no more than 1 hour for detection and correction.

C. RECOMMENDATIONS

From the examination of the JAGM, GMLRS, and PAC-3 testing projects, the following recommendations are made:

- Reduce Non-track Optics set-up time to cut customer cost, reduce schedule pressures that are the result of secondary effects of evacuations, roadblocks and other restrictions imposed by the range schedule. Target estimated cost avoidance of $70,000/year.
- Reduce labor required for setup by at least 15%, depending on mission requirements. Reduction of these set up times could also significantly increase mission throughput, resulting in higher reimbursable return and increased schedule availability and flexibility to the customer.
- Present customer with agreement plan to tailor test around new permanent infrastructure. This would provide improved sites with better reliability, security and availability. Permanent infrastructure at test site would include surveyed camera equipment and intact communications equipment, including data lines. Target goal should be an average of 9 missions per year at each designated permanent infrastructure/site. Attempt to avoid site reconfiguration due to changing customer requirements.
- Reduce the amount of time detecting and correcting TACLANE failures, which would lead to customer financial savings.
- Procure new TACLANES to be readily available with secured network capabilities and be staged strategically throughout the range. This would require further review of existing TACLANE inventory to determine any

potential sharing, re-staging, etc. that could eliminate potential choke points in the process. The procurement of more equipment would also require recruiting additional trained personnel to program the TACLANES in the south, central and north parts of WSMR.

D. AREAS FOR FURTHER RESEARCH

The following areas were seen as open issues beyond the scope of this JAP and are recommended for further research:

Permanent Infrastructure

- Discuss with WSMR Environmental Department about archaeological sites and conflict with building permanent infrastructure.
  - How flexible can we be on placement should we have to work around a site?
- Discuss safety aspects
  - Digging in an Impact area
    - Chances of encountering unexploded ordnance (UXO)
- Talk to test officers about customer requirements?
  - How flexible are customers willing to be?
  - Will they accept fixed camera sites?
- Engineering.
  - Is the scope of this project reasonable and affordable?
- Funding
  - Are customers willing to contribute?
  - Is there Army money available?

Network Equipment

- Equipment Requirements
  - Are all TACLANE models considered?
  - What models will be used in the future?
  - Will more TACLANES be needed?
- Training Requirements
  - Will this be an annual requirement?
  - Are there enough personnel trained?

- WSMR Staging Layout
  - Is the staging layout of this project reasonable?
- Funding
  - Are customers willing to contribute?
  - Is there ATEC money available?

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