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AIR FORCE SPACE SENSOR STUDY (U)

AFPEO/SP

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Air Force Space Sensor Study (U)

(U) The following briefing provides U.S. Air Force development and operational community evaluations of alternative satellite architectures to provide global tactical warning/ attack assessment (TWAA) and ballistic missile defense(BMD) over-the-horizon interceptor commit information. The Follow-on Early Warning System (FEWS) and Brilliant Eyes (BE) developments are intended to provide our 21st century capability.

(U) The alternatives were chosen to represent the most promising system architectures and reflect technical feasibility and operational suitability considerations. No industrial base considerations were addressed.

(U) The study was begun once the FEWS and the Brilliant Eyes programs awarded their Demonstration/Validation contracts. Until then, it was not possible for the government to obtain meaningful contractor inputs which would relate to actual system designs. A government response to Congressional concerns without this foundation of actual contractor designs would not carry as much weight in its final conclusions. The FEWS contracts were awarded in July 1992 and the Brilliant Eyes contracts were awarded in December 1992.

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PURPOSE

PRESENT STUDY RESULTS ON ALTERNATIVE SPACE BASED TWAA AND BMD INTERCEPTOR COMMIT SYSTEMS IN RESPONSE TO FY 92 CONGRESSIONAL LANGUAGE

BASIC QUESTION: CAN WE SAVE MONEY BY COMBINING FUNCTIONS?

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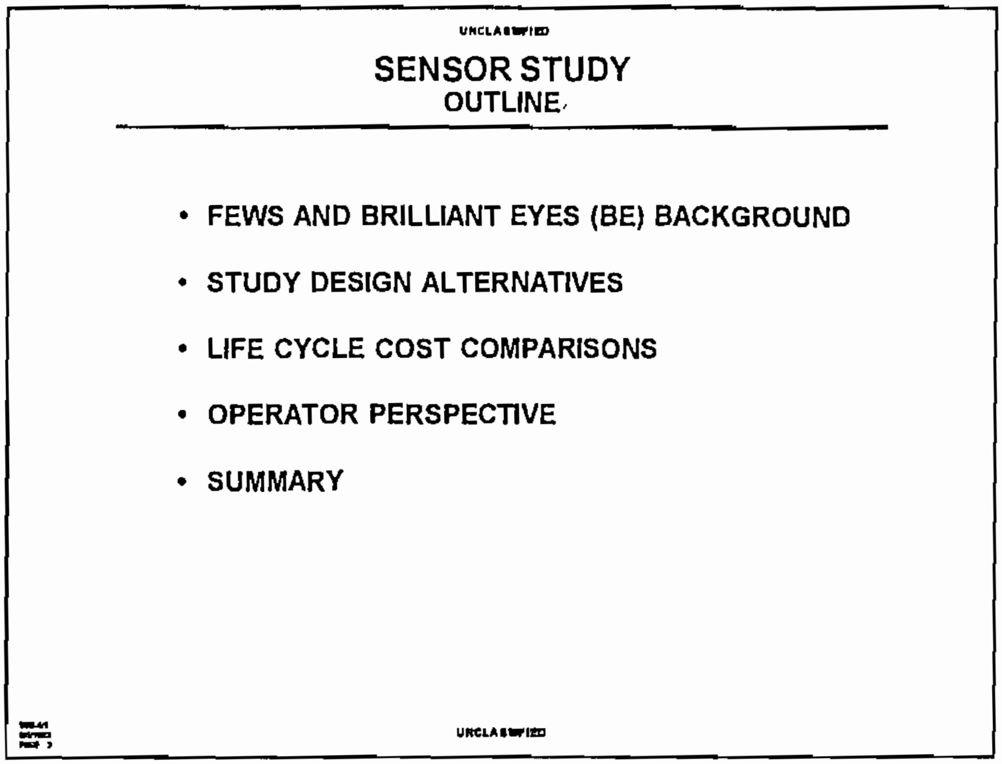
Purpose (U)

(U) This study resulted from a November 1992 Air Force tasking letter directing an effort to investigate three alternatives to the current FEWS and BE systems. These alternatives (to be described later) were chosen in response to fiscal year 1992 congressional language. Now that both programs are included under the PEO management structure, we are examining the potential advantages of modifications to the FEWS and BE baselines which opitimize total system performance at a potential lower cost. We addressed the alternatives against the existing Follow-On Early Warning System and Brilliant Eyes operational and design requirements.

(U) The congressional language and Air Force tasking address a basic question: Can we save money by combining functions?



Sensor Study Outline (U)

(U) The briefing outline is as shown.

(U) The FEWS and Brilliant Eyes attributes, FEWS and BE programs, and contributions to TWAA and BMD constitute a primer on the mission areas, spacecraft roles within these mission areas, spacecraft development schedules, and operational performance perspectives.

(U) The alternatives section presents the study's technical results.

(U) Life cycle cost sensitivities and comparisons provide the cost information (best estimates) for all alternatives investigated and describe uncertainties associated with these cost estimates.

(U) The operator's perspective on the alternatives addresses operational risk and suitability.

(U) Findings and recommendations complete the package.

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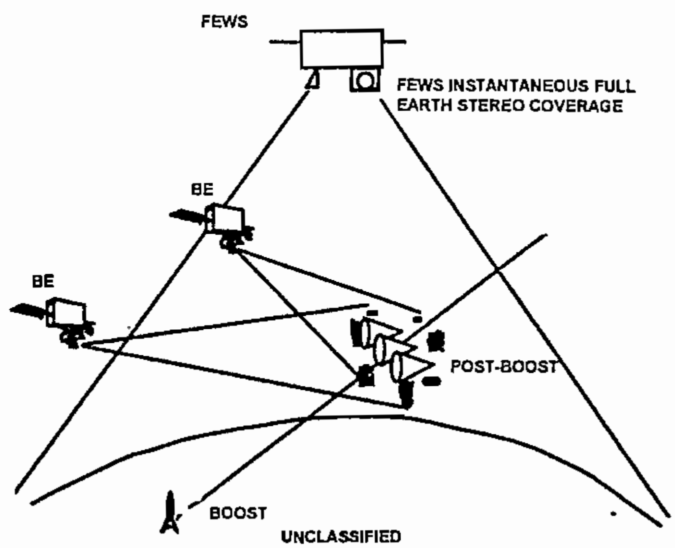
BACKGROUND (U)
TWAA AND INTERCEPTOR COMMIT MISSIONS

FEWS/BE ROLES



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Background: TWAA and Interceptor Commit Missions (U)

(U) The respective roles of the Follow-On Early Warning System and Brilliant Eyes are shown in context of Ballistic Missile Warning and Defense.

(U) FEWS has responsibility for global surveillance and warning of tactical and strategic missile launch events. Each satellite provides near hemispherical coverage for tracking boosting missiles in the short (SWIR) and medium (MWIR) wave infrared bands. It enables BMD battlespace extension through fine cue hand -off to the indigenous fire control radar. In addition, FEWS provides surveillance hand-off to the BE acquisition mode for subsequent tracking and processing.

(U) BE has responsibility for acquisition and fine tracking of ballistic missiles, missile upper stages, post-boost vehicles, reentry vehicles, and other objects. It does this through the use of visible, SWIR, MWIR, and Long Wave (LWIR) infrared sensors. Its design enables BMD interceptor commit beyond indigenous radar line of sight.

(U) This satellite architecture provides tracking capability through the complete missile flight envelope enabling accurate launch and impact point prediction, threat typing, raid assessment, and interceptor - warhead kill assessment.

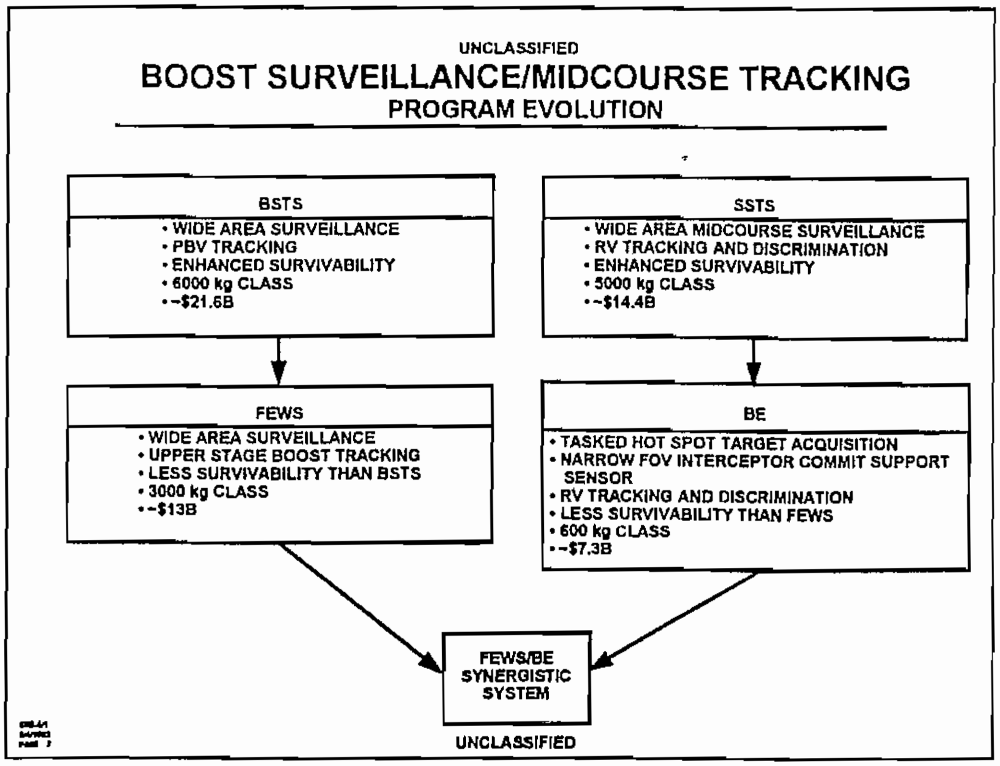
FEWS/BE Primary Missile Tracking Capabilities (U)

(U) The Follow-On Early Warning System and Brilliant Eyes capabilities to track ballistic missiles from launch to reentry are depicted on this notional missile flight time versus missile radiant intensity chart. The vertical axis (radiant intensity) is expressed in watts per steradian. The flight time axis is notional with only the booster burnout event marked.

(U) When the Post Boost Vehicle (PBV) energy output drops below the FEWS capability, BE's lower altitude and MWIR sensors enable continuous tracking at distances of several thousand miles.

Below The Horizon (BTH) Coverage (U)

(U) The smallest ellipse shows the BE BTH access (capable of viewing but not simultaneously processing). The small sized shaded circle near the ellipse's upper edge shows the BE coverage capability. This limited coverage is sufficient for BE to take an early hand-over from FEWS and improve state vector accuracy or acquire threats in a pre-designated area. This is especially important for the compressed timelines associated with acquisition and track of short burn time missiles launched under a cloud deck.



Boost Surveillance/Midcourse Tracking Program Evolution (U)

(U) Today's FEWS and Brilliant Eyes operational and design requirements reflect a significant time and dollar expenditure evolutionary path.

(U) The current FEWS program comes from the Boost Surveillance and Tracking System (BSTS) which combined world-wide surveillance with post-boost vehicle tracking. Today's FEWS retains only the world-wide surveillance mission.

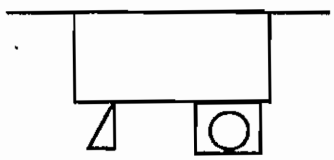
(U) BE's legacy derives from the Space Surveillance and Tracking System (SSTS) which attempted to couple wide area surveillance with Reentry Vehicle (RV) tracking and discrimination. More than one billion dollars has been spent on these and other activities leading to the current BE requirements baseline.

(U) The evolutionary approach benefits are shown: a 50% decrease in boost phase surveillance satellite weight and projected 40% decrease in Life Cycle Cost (LCC); and an 85+% decrease in interceptor commit satellite weight and projected 50% decrease in LCC.

U) An examination of an "integrated" FEWS/BE architecture is underway. Several areas of potential savings exist for the synergistic design and deployment of these two systems.

TWAA AND BMD SATELLITE PROGRAMS (U)

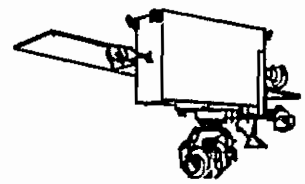
FOLLOW-ON EARLY WARNING SYSTEM (TWAA)



SCHEDULE
- TWO CONTRACTORS, TWO YEAR DEM/VAL, PRODUCIBILITY DEMO
- EMD IN FY94, ONE CONTRACTOR

COST
- ACQUISITION PHASE
  COST OF $9B/(FY93$)
- O&S PHASE
  COST (10 YR OPERATIONS) $4B/(FY93$)

BRILLIANT EYES (BMD)



SCHEDULE
- TWO CONTRACTORS
- ONE CONTRACTOR FOR EMD

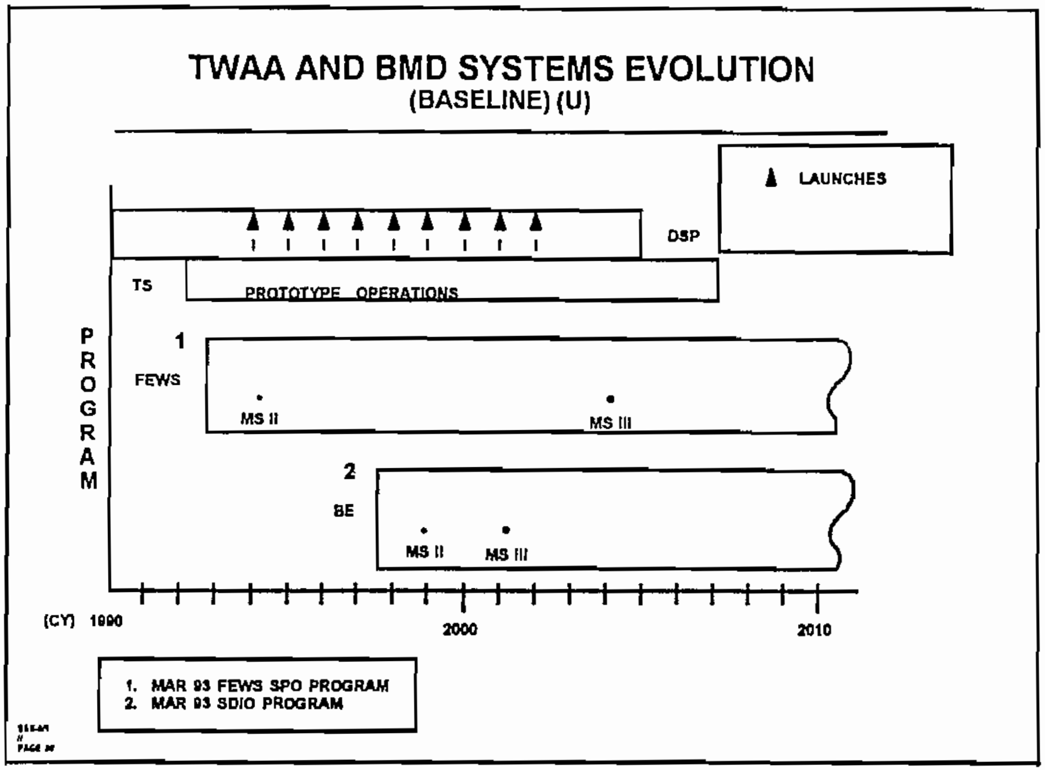
COST
- ACQUISITION PHASE
  COST OF $5B/(FY93$)
- O&S PHASE
  COST (10 YEAR OPERATIONS) $2.3B/(FY93$)

TWAA and BMD Satellite Programs (U)

(U) Life Cycle Costs are captured from Fy1993 - FY2015 for this study

(U) The Follow-On-Early Warning System is shown on the left. The program is currently in demonstration/validation with two competing contractors - Lockheed and TRW. The program office will down-select to a single EMD contractor in FY94. The life cycle cost (FY93 $) for FEWS is projected at approximately $13 billion - $9 billion in RDT&E, launch, and O&S during the acquisition phase; and $4 billion in replenishment production, launch, and O&S during the subsequent 10 year operations period.

(U) The Brilliant Eyes (BE) system is shown on the right. BE entered the flight demonstration/validation phase in December 1992 with two contractors - TRW and Rockwell. There will be a MSII decision in FY98, a single EMD contractor. BE's LCC (FY93 $) is $7.3 billion; $5 billion for RDT&E, launch and O&S during the acquisition phase;and $2.3 billion for replenishment, production, launch, and O&S during the subsequent 10 year operations period.



TWAA and BMD Systems Evolution (U)

(U) This slide shows the relative phasing of the current DSP (including Talon Shield -TS), FEWS, and BE programs.

(U) DSP launches will continue until early in the 21st century at which time the initial FEWS satellite launches occur. Talon Shield, currently a SDIO-funded activity, is a ground processing/tactical exploitation enhancement to the existing DSP capability. It is funded through a prototype operational demonstration in FY94.

(U) FEWS will go through a Milestone II review in FY94.

(U) BE will go through a Milestone II review in FY98.

FEWS/BE SYNERGISM (U)

- FEWS PROVIDES TO BE
  - WORLD WIDE SITUATIONAL MAP
  - CUEING VIA EARLY LAUNCH DETECTION

- BE CAN BE TASKED TO AUGMENT FEWS
  - BUS TRACKING
  - DUAL PHENOMENOLOGY

Synergism (U)

(U) FEWS can provide worldwide situational awareness to enable efficient BE utilization. FEWS provides BE timely cueing from early launch detection and accurate state vector handover.

(U) BE can be cued by FEWS to provide dual phenomenalogy to satisfy TW/AA attack assessment needs. The BE sensor suite provides the capability to track very dim targets.

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FEWS VICE DSP (U)

- SENSITIVITY
  - ADDS MWIR FOR DIM TARGETS
  - SELECTABLE THRESHOLD (2-15 TIMES BETTER)
  - PERMITS BOOSTER TRACKING THROUGH BURNOUT
- UPDATES
  - SELECTABLE (2 TO 10 TIMES BETTER)
  - PROVIDES QUICK STATE VECTORS
  - SHORT REVISITS SUPPORT SHORT-BURN EVENTS
- MORE AFFORDABLE
  - RECURRING COSTS ARE LESS
  - PRE-PLANNED GROWTH POTENTIAL
  - REDUCED NUMBER OF GROUND STATION PERSONNEL

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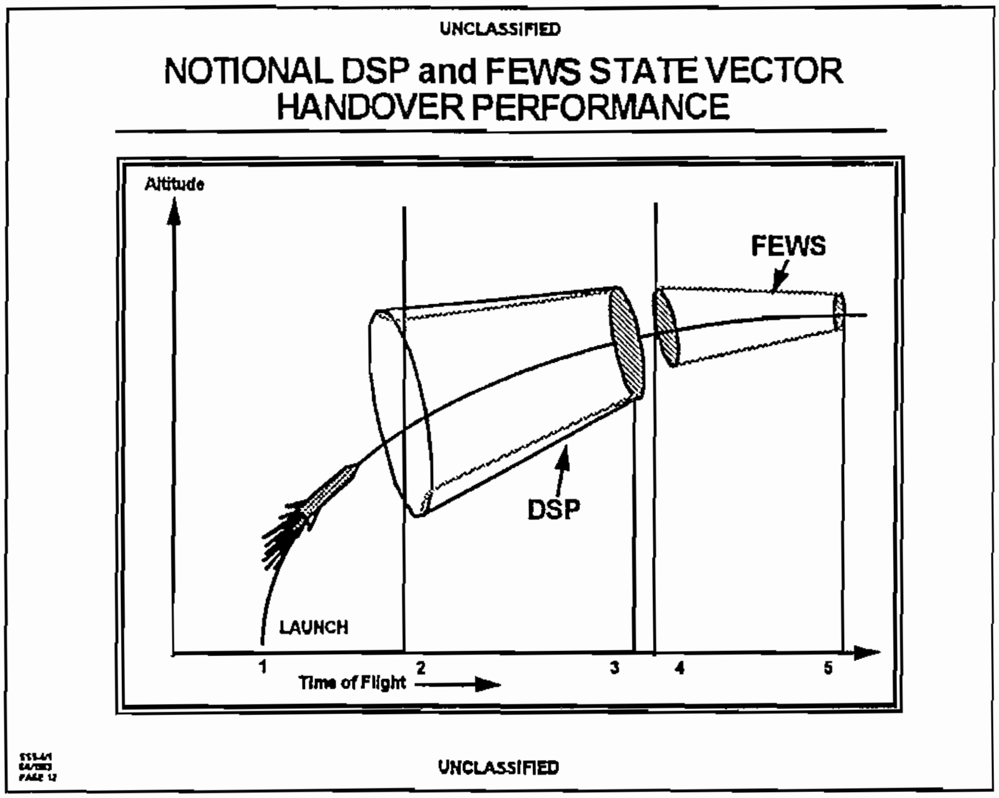
FEWS Vice DSP

(U) Sensitivity, update rate, enhanced connectivity (through cross-links, on board data processing, direct message to user) and affordability are the three key factors differentiating FEWS from the current DSP. The first two address our military capability to detect, classify, and respond against fast-burn theater through strategic ballistic missiles.

(U) Greater Short Wave Infrared (SWIR) and Medium Wave Infrared (MWIR) sensitivity permits more reliable detection of short range theater ballistic missiles (that DSP was not designed to detect or report) and also enables tracking threat missiles until booster burnout.

(U) Faster update rate is critical to theater operations to minimize delayed warning in time critical, cloud limited operations. IR sensors cannot see through clouds. An effective system must be designed to provide a militarily useful product under all field operating conditions. Quick state vector development is required to provide timely warning to the theater war fighters.

(U) The new technology provided by FEWS not only offers operational flexibility to respond to threat uncertainties of the future, but also results in recurring space vehicle costs that are lower than those of DSP. FEWS eliminates dependence on overseas ground stations. With the new technology of FEWS, spacecraft autonomy results in a 50% reduction in ground station manpower.



Notional DSP and FEWS State Vector Hand-Over Performance (U)

(U) This notional chart depicts two important differences between the current DSP system and the Follow-On Early Warning System in development: Track Duration and resulting Tracking Accuracy.

(U) The vertical axis represents ballistic missile altitude and the horizontal axis represents missile time of flight. The horizontal axis depicts from left to right.

(1) The missile launch;

(2) TWAA system (DSP or FEWS) missile acquisition and track file development;

(3) Missile plume intensity falls below DSP SWIR threshold (drop track);

(4) Missile plume intensity falls below FEWS SWIR threshold (MWIR track); and

(5) Missile signature intensity falls below FEWS MWIR threshold (drop track)

(U) FEWS sample rate and dim target tracking capability are both an order of magnitude better than DSP. This combination results in faster minimum target position and velocity error convergence, lower minimum error basket, lower error growth rate (after booster burnout), and smaller launch and impact point prediction error.

(U) The ability of FEWS to track dim upper stages to burnout and to track them more accurately, provides a minimum azimuth error and handover state vector that is projected to be 10 times better than that from DSP for strategic missiles and four times better for tactical missiles.

TWAA UTILITY FOR THEATER OPERATIONS LAUNCH LOCATION ACCURACY (U)

(U) Ballistic Missile Defense includes not only the destruction of the incoming threat missile, but the destruction of the threat launcher.

(U) DSP cannot see some tactical threats due to high clouds and/or short burn times, and therefore, cannot reliably estimate launch locations.

(U) FEWS, with its sensor accuracy and increased sample rate, reduces this search area. Once the launcher moves away from the launch point, its position uncertainty grows further. Consequently FEWS faster report time and direct downlink to the theater also contribute to minimizing the search area. FEWS increases the likelihood of successful target handover to airborne surveillance (TR-1, JSTARS) or hunter-killer assets (e.g. counter battery rocket launcher, F15-E Strike Eagle). FEWS provides much increased probability of launcher destruction; and the faster warning time and improved location accuracy allows fewer aircraft to be dedicated to counterforce mission.

TWAA UTILITY FOR THEATER OPERATIONS
IMPACT POINT PREDICTION (U)

(U) Impact Point Prediction (IPP) is important in a tactical operations scenario. Estimated impact area determines what cities or military facilities are under attack, which missile defense batteries must be activated, which assets must be sortied or passively protected, and which personnel must don chemical or biological protective clothing.

(U) Post mission analysis of DSP performance during Desert Storm has demonstrated improved heading accuracies and warning times by the stereo processing of two-satellite detections of threat missiles and the use of missile time-intensity templates to more accurately estimate missile burnout conditions. Post-mission performance analysis is indicated on the chart.

(U) FEWS increases the warning time by its faster revisit time and by stereo processing and predicting the impact point on-orbit, with warning messages sent directly to all in-theater users. The greater sensor sensitivity, faster revisit time (more track data per missile) and dual processing results in 4-fold increase in heading accuracy over operational DSP performance. This translates into a city versus region IPP.

TWAA UTILITY FOR STRATEGIC OPERATIONS

MWIR PROFILE (U)

(U) The most demanding strategic TW/AA capability is ICBM upper stage tracking as illustrated by this chart.

TWAA UTILITY FOR STRATEGIC OPERATIONS

NOTIONAL IMPACT POINT PREDICTION VS TRACK DURATION FOR SS-19 (U)

(U) Impact Point Prediction (IPP) is an important TWAA performance parameter for both strategic and tactical military operations support. It provides an alert to personnel and equipment in the threatened impact area, warning for threatened resources and activates active and passive missile defense activities.

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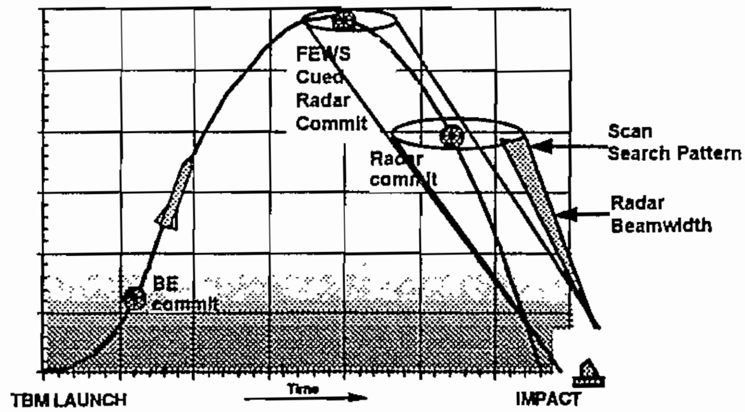
BOOST SURVEILLANCE/INTERCEPTOR COMMIT SYSTEMS SUPPORT TO ACTIVE MISSILE DEFENSE (U)

•**Extends Interceptor Battle Space via Early Commit by:**
  - **Tracks Threats Launched Outside of Radar Coverage**



Radar assumed to have 500 km range; cueing doubles range by reducing search area by factor of 16

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Boost Surveillance/Interceptor Commit Systems Support to Active Missile Defense (U)

(U) FEWS and BE can make a significant contribution to Ballistic Missile Defense (BMD) system effectiveness by permitting earlier interceptor launch. This is accomplished by (1) decreasing the radar search envelope and (2) providing state vector information of sufficient accuracy to launch interceptors beyond the radar horizon.

(U) The chart depicts theater ballistic missile launch on the left with flyout occurring towards the right. The vertical axis is missile altitude in kilometers and horizontal axis is flight time in seconds. The example shown reflects a 2000 kilometer missile with the BMD system col-located within the target area.

(U) FEWS can approximately double the theater interceptor battle space (GBR-like radar engagement range) from 500 to 1000 kilometers for missiles with ranges greater than 2000 km. BE, given either a FEWS cue or hot spot detection and acquisition, can provide launch quality state vectors to the Joint Forces Air Component Commander before the missile begins exoatmospheric flight.

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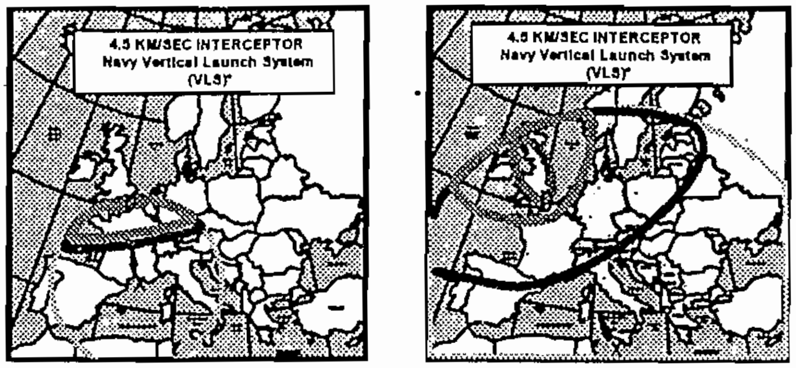
BOOST SURVEILLANCE / INTERCEPTOR COMMIT SYSTEMS INCREASE BALLISTIC MISSILE DEFENSE AREA

- Greater Enhancement For Threats Launched Beyond Radar Coverage



1000 km Range Threat Missile

3000 km Range Threat Missile

Radar Commit
FEWS Cued Radar Commit
BE Commit

* A TMD GBR RADAR CAPABILITY USED

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Boost Surveillance/Interceptor Commit Systems Increase Ballistic Missile Defense Area (U)

(U) FEWS and BE offer a several-fold increase in defended area for the Army THAAD and Navy Vertical Launch System (VLS) against ballistic missiles with ranges greater than 600 kilometers (km). The pictorials depict the Navy VLS system capability with (GBR-like radar) under three sensor conditions (Stand-Alone Radar, FEWS cued Radar, and BE State Vector Interceptor Commit) and two threat missile ranges (1000 km and 3000 km).

(U) The left picture shows the current VLS design forward defense exoatmospheric intercept capability as being limited to the ship vicinity. With FEWS cueing, an English channel based AEGIS could extend protection to northern France, Belgium and southeast Germany. The defended area is only slightly increased with the addition of the BE system for the shorter range threat. The threat is off the French coast in the Mediterranean looking north for the 1000 km case.

(U) A 3000 km range ballistic missile launched towards Western Europe could threaten the area (including western CIS) within the large circle. The indigenous VLS capability has less forward defense capability than previously shown due to greater threat missile velocity. It could defend now threatened areas of Great Britain behind the ship. FEWS cueing provides little additional forward defense but a 4-5 fold increase in total defended area. BE coupled with the VLS interceptor enables the single battery to cover large areas of Western Europe, the Baltic states, and southern Norway.

(U) TMD Ground Based Radar was used in the analyses with a nominal 500 KM radar range (without cueing), nominal 1,000 KM radar range (with cueing).

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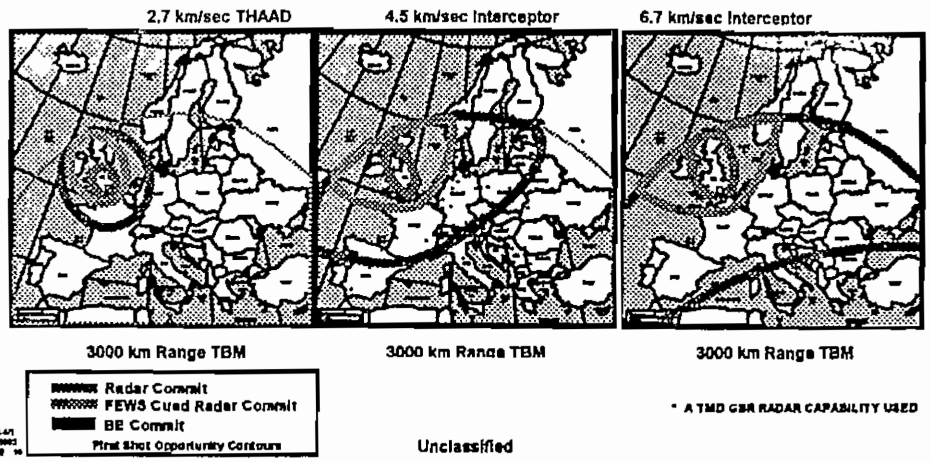
BOOST SURVEILLANCE/INTERCEPTOR COMMIT SYSTEMS MAXIMIZE MISSILE PERFORMANCE

- Defended Area Becomes Dependent on Defense Interceptor Performance*
  - Increases Defended Area
  - Enables Defense from Greater Stand-off Ranges



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Boost Surveillance/Interceptor Commit Systems Maximize Performance (U)

(U) Against threats of 2000 km or more, interceptor performance becomes important in minimizing the number of deployed defense sites. This view graph depicts the defended area coverage improvements as the defense interceptor burnout velocity increases (from left to right). TMD Ground Based Radar was used in the analyses with a nominal 500 KM radar range (without cueing), nominal 1,000 KM radar range (with cueing).

(U) These charts illustrate how interceptor performance couples with over-the-horizon missile launch detection and/or tracking systems. A 3000 km missile launched from North Africa against targets in East and West Europe is depicted. The defense site is located either outside London (6.7km/s) or in the English Channel (4.5 km/s). Three defended area contours are depicted: inner- BMD radar/interceptor capability; middle-BMD radar cue by FEWS/interceptor capability; and outer-interceptor launch using information from Brilliant Eyes.

(U) Radar cueing by FEWS and BE interceptor commit expands the Theater High Altitude Air Defense (THAAD) system defense coverage by many fold over the intrinsic system as shown in the THAAD panel. Item of note - The area expansion from FEWS cueing and BE commit indicates that the radar is range limited relative to the interceptor performance.

(U) Using a Navy Vertical Launch System - with a 4.5km/s interceptor, the ground based system defended area increases by 100% over THAAD. With FEWS cueing, this defended area increases by a factor of four. Finally interceptor launch using BE state vector information results in a dramatic defended area increase. This provides a meaningful defense of Western European land mass.

(U) For the ground radar and FEWS-cued radar configuration, defended area does not significantly increase with an additional 50% increase in interceptor velocity (6.7km/s). However with BE interceptor commit, most of the threatened European land mass has a single shot/salvo opportunity from the "Britain" based site. This BE /interceptor combination reflects capabilities now being designed for National Missile Defense.

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SENSOR STUDY
OUTLINE

- FEWS AND BRILLIANT EYES (BE) BACKGROUND
- STUDY DESIGN ALTERNATIVES
- LIFE CYCLE COST COMPARISONS
- OPERATOR PERSPECTIVE
- SUMMARY

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STUDY ALTERNATIVES

FEWS/BL	HIGH ALTITUDE, MULTI-MISSION SATELLITE CONSTELLATION PROVIDING GLOBAL TWAA
BE/BL	LOW ALTITUDE, DISTRIBUTED SATELLITE CONSTELLATION OF MULTI-MISSION SATELLITES PROVIDING BMD INTERCEPTOR COMMIT
TWAA/BMD:	LOW ALTITUDE, DISTRIBUTED SATELLITE CONSTELLATION OF MULTI-MISSION SATELLITES DOING GLOBAL TWAA AND BALLISTIC MISSILE INTERCEPTOR COMMIT
LA/TWAA:	LOW ALTITUDE, DISTRIBUTED, MULTI-MISSION SATELLITE CONSTELLATION DOING GLOBAL TWAA
DSP^{++} + BE:	HIGH AND LOW ALTITUDE MIX OF MODIFIED DSP SATELLITES TWAA AND BRILLIANT EYES TO DO GLOBAL BALLISTIC MISSILE INTERCEPTOR COMMIT.

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Study Alternatives

(U) At this point we now transition to the study results which address various implementations for Tactical Warning/Attack Assessment (TWAA) and Ballistic Missile Defense (BMD).

(U) Five system configurations are listed: present FEWS baseline program, present BE, baseline program, an expanded BE to do low altitude, distributed, global TWAA along with Ballistic Missile Defense (TWAA/BMD), a low altitude, distributed FEWS system to do global TWAA (LA/TWAA) and an upgraded DSP combined with BE to do the global TWAA and BMD missions (DSP^{++} and BE).

(U) The FEWS and BE baseline programs have been previously described. The following sections will describe the TWAA/BMD, LA/TWAA, and DSP^{++} + BE alternatives, their cost, and operator perspectives on their suitability.

LOW ALTITUDE TWAA/BMD SATELLITE CONCEPT (U)

(U) An upgraded Brilliant Eyes (BE) low altitude satellite that meets FEWS Operational Requirements Document (ORD) and BE provisional performance criteria capability is shown.

Operations

(U) The low altitude TWAA/BMD satellite uses two sensor assemblies to perform its mission. The first sensor is a wide Field Of View (FOV) Below-The-Horizon (BTH) scanner and the second sensor is a narrow FOV BTH and Above the Horizon (ATH) agile sensor/starer.

(U) The wide FOV BTH scanner continuously sweeps out a conical scan about nadir that covers to the horizon plus 500 km altitude. The scanner provides global TWAA surveillance, track to missile burnout and surveillance of Areas Of Interest (AOI) signatures. In addition, the wide FOV BTH scanner initiates booster track files and provides initial Line of Sight (LOS) pointing data for the narrow FOV agile sensor.

(U) The narrow FOV starer is used to continuously track objects after burnout. The starer contains four different wavelength focal plane arrays (SWIR, MWIR, LWIR & Visible) that track boosters, PBVs, and warheads during various flight phases. The narrow FOV starer has the additional capability of detecting and tracking of lower intensity AOI signatures. The midcourse function takes precedence over the AOI function should the need arise for both to be performed simultaneously.

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LOW ALTITUDE TWAA/BMD SATELLITE CONCEPT RISK ANALYSIS (U)

- RISK ANALYSIS PERFORMED ON SPACE SEGMENT USING INPUTS FROM INDEPENDENT TECHNICAL TEAM
- NINE SUBSYSTEMS ASSESSED: FPA, OTA, GIMBALS, CRYO-COOLING, SIGNAL PROCESSING, SPACECRAFT BUS, DATA PROCESSING, COMMUNICATIONS, SURVIVABILITY
- NINE SEPARATE CATEGORIES ASSESSED FOR EACH SUBSYSTEM; E.G. REQUIRED TECHNICAL ADVANCEMENT, RELIABILITY, ETC.
- WEIGHTED AVERAGE RISK FACTOR DERIVED FOR EACH SUBSYSTEM
- CRYO-COOLER RATED HIGHEST RISK FOR THIS TASK
- WEIGHTED FACTORS USED AS WORST CASE COST INPUT TO FRISK RISK MODEL
- PROBABILITY DISTRIBUTIONS AT 50TH PERCENTILE RESULTED IN A RISK PERCENTAGE OF 22% FOR SPACE SEGMENT
- GROUND SEGMENT RISK ASSESSED AT 15% FOR NONRECURRING COSTS AND 8% FOR RECURRING COSTS

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LOW ALTITUDE TWAA/BMD SATELLITE CONCEPT RISK ANALYSIS (U)

(U) A risk analysis was performed on the space segment using inputs provided by an independent technical team. The team was asked to complete a technical assessment of nine subsystems that were determined to contain some technical risk. The following subsystems were rated by the team: Focal Plane Array; Optical Telescope Assembly; Gimbals; Cryo-cooler; Signal Processing; Spacecraft Bus; Data Processing; Communications; Survivability. The team used a matrix containing nine categories in their assessment: Required Technical Advancement; Technology Status; Complexity; Interaction or Dependencies on Other Risk Drivers; Manufacturing Process Controls; Manufacturing Precision Capability; Reliability; Producibility; Criticality to Mission. Each of these categories was rated Low to High Risk on a nonlinear scale from 1.25 to 5.0 (Low to High Risk) for nonrecurring and 1.125 to 3.0 for recurring costs. All of the ratings for each category were added up and averaged based on a weighted scale. Each of the nine categories was weighted based upon its impact on costs. The weightings assigned varied depending on the subsystem.

(U) For this task, the highest risks were assigned to the cryo-cooler, gimbal, focal plane array, and survivability. The cryo-cooler ratings were medium-high to high risk.

(U) Once the weighted factors were derived for each subsystem, they were used as inputs in the Frisk Risk model developed by the Aerospace Corporation. These risk factors represented the worst case costs by subsystem. The "best estimates" combined with the technical risk analysis resulted in a probability distribution of costs for each subsystem. The probability distributions were then summed statistically and the 50th percentile costs derived for the total space segment. The difference between the 50th percentile costs and the total "best estimate" represents the risk dollars associated with the space segment.

(U) Risk dollars represented approximately 22% of total space segment costs. Ground system risk was derived using a straight percentage of total ground costs: 15% for nonrecurring and 8% for recurring.

LOW ALTITUDE TWAA SATELLITE CONCEPT (U)

(U) The current FEWS system modified for low altitude distributed architecture operation is shown. This satellite is designed solely for the TWAA mission and would be used in concert with Brilliant Eyes for Ballistic Missile Defense interceptor over-the-horizon commit.

Operations

(U) Low altitude TWAA satellite uses two SWIR/MWIR sensors. One sensor has a fixed revisit rate and scans the earth from nadir to horizon, providing global TWAA surveillance. The other sensor is agile and can be pointed at areas of interest (including the dim, upper stages of targets detected by the global scanner). The agile sensor has a narrow FOV that can be scanned at various revisit rates to enhance sensitivity. This allows track to burnout and flexible AOI scanning. While the technical design differs from the previous TWAA/BMD, they are functionally equivalent.

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LOW ALTITUDE TWAA SATELLITE CONCEPT RISK ANALYSIS (U)

- RISK ANALYSIS PERFORMED ON SPACE SEGMENT USING INPUTS FORM INDEPENDENT TECHNICAL TEAM
- NINE SUBSYSTEMS ASSESSED: FPA, OTA, GIMBALS, CRYO-COOLING, SIGNAL PROCESSING, SPACECRAFT BUS, DATA PROCESSING, COMMUNICATIONS, SURVIVABILITY
- NINE SEPARATE CATEGORIES ASSESSED FOR EACH SUBSYSTEM; E.G. REQUIRED TECHNICAL ADVANCEMENT, RELIABILITY, ETC.
- WEIGHTED AVERAGE RISK FACTOR DERIVED FOR EACH SUBSYSTEM
- CRYO-COOLER RATED HIGHEST RISK FOR THIS TASK
- WEIGHTED FACTORS USED AS WORST CASE COST INPUT TO FRISK RISK MODEL
- PROBABILITY DISTRIBUTIONS AT 50TH PERCENTILE RESULTED IN A RISK PERCENTAGE OF 22% FOR SPACE SEGMENT
- GROUND SEGMENT RISK ASSESSED AT 15% FOR NONRECURRING COSTS AND 8% FOR RECURRING COSTS

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LOW ALTITUDE TWAA SATELLITE CONCEPT RISK ANALYSIS (U)

(U) A risk analysis was performed on the space segment using inputs provided by an independent technical team. The team was asked to complete a technical assessment of nine subsystems that were determined to contain some technical risk. The following subsystems were rated by the team: Focal Plane Array; Optical Telescope Assembly; Gimbals; Cryo-cooler; Signal Processing; Spacecraft Bus; Data Processing; Communications; Survivability. The team used a matrix containing nine categories in their assessment: Required Technical Advancement; Technology Status; Complexity; Interaction or Dependencies on Other Risk Drivers; Manufacturing Process Controls; Manufacturing Precision Capability; Reliability; Producibility; Criticality to Mission. Each of these categories was rated Low to High Risk on a nonlinear scale from 1.25 to 5.0 (Low to High Risk) for nonrecurring and 1.125 to 3.0 for recurring costs. All of the ratings for each category were added up and averaged based on a weighted scale. Each of the nine categories was weighted based upon its impact on costs. The weightings assigned varied depending on the subsystem.

(U) For this task, the highest risks were assigned to the cryo-cooler, gimbal, focal plane array, and survivability. The cryo-cooler ratings were medium-high to high risk.

(U) Once the weighted factors were derived for each subsystem, they were used as inputs in the Frisk Risk model developed by the Aerospace Corporation. These risk factors represented the worst case costs by subsystem. The "best estimates" combined with the technical risk analysis results resulted in a probability distribution of costs for each subsystem. The probability distributions were then summed statistically and the 50th percentile costs derived for the total space segment. The difference between the 50th percentile costs and the total "best estimate" represents the risk dollars associated with the space segment.

(U) Risk dollars represented approximately 20% of total space segment costs. Ground system risk was derived using a straight percentage of total ground costs: 15% for nonrecurring and 8% for recurring. The analysis was done at the lowest level of estimating (component in most cases) for all segments of the program and resulted in an overall percentage risk of 9% at the 50th percentile.

DSP^{++} AND BE

DSP^{++} (HIGH ALTITUDE TWAA) & BE (LOW ALTITUDE BMD) CONCEPT (U)

(U) This option is a hybrid concept, consisting of both high-altitude and low-altitude elements. The high altitude component is a significantly upgraded Defense Support Program (DSP) satellite (an upgrade option studied in the 1991 FEWS COEA). The low altitude element is the Government baseline Brilliant Eyes (BE) system. Without modification (to enable DSP to rapidly cue BE and centrally fuse data from both systems), the baseline BE system cannot contribute to the TWAA mission. Therefore, TWAA requirements are allocated to DSP and BMD requirements to BE.

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DSP^{++} AND BRILLIANT EYES RISK ANALYSIS (U)

- RISK ASSESSED AT 15% NONRECURRING AND 10 % RECURRING FOR DSP^{++} OPTION
- BRILLIANT EYES SYSTEM USED IN CONCERT WITH THIS TASK USED PROBABILISTIC RISK MODEL IN ITS ASSESSMENT
- BE RISK ASSESSED AT 9% AT THE 50TH PERCENTILE

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DSP AND BRILLIANT EYES RISK ANALYSIS (U)

(U) This concept was incorporated unchanged from the 1991 FEWS Milestone I Review COEA. At that time risk was assessed as a straight percentage for the DSP++ option: 15% for nonrecurring and 10% for recurring. The total risk dollars were then distributed among the WBS elements based upon estimator judgment. We were unable to apply the risk methodology used in this study due to the lack of subsystem-level design information. The Brilliant Eyes baseline system used in concert with this task conducted a detailed risk analysis utilizing a probabilistic risk model. The analysis was done at the lowest level of estimating (component in most cases) for all segments of the program and resulted in an overall percentage risk of 9% at the 50th percentile.

(U) DSP++ 's lower sensitivity and report timeliness reduce potential TWAA - to - BE handoff effectiveness and limits any potential savings of an integrated architecture.

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SENSOR STUDY
OUTLINE

- FEWS AND BRILLIANT EYES (BE) BACKGROUND
- STUDY DESIGN ALTERNATIVES
- LIFE CYCLE COST COMPARISIONS
- OPERATOR PERSPECTIVE
- SUMMARY

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(U) This section presents life cycle cost (LCC) data for the following TWAA and combined TWAA/BMD system configurations: FEWS/BL, FEWS/BL + BE/BL, TWAA/BMD, LA/TWAA, DSP^{++}, and DSP^{++} +BE/BL. These LCC cost data have two components: the best estimate LCC cost including adjustments for technical risk, and an uncertainty region. The uncertainty region addresses the effect on LCC of first unit (T1) cost, mean mission duration (MMD), and production learning curves sensitivities.

(U) Since the alternatives lack the design maturity of FEWS and BE (both programs recently completed System Requirement Reviews), the uncertainty region has important implications. MMD dominates, followed by T1 cost then production learning curve sensitivity. MMD and production learning curve sensitivities will be graphically displayed and discussed. First unit cost variance (T1) between high and low altitude satellites is not discussed further (its cost impact is included in the uncertainty calculations).

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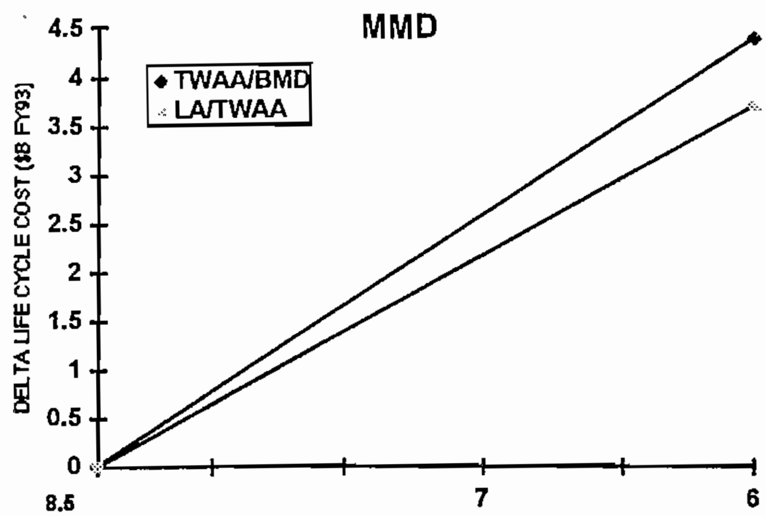
TWAA/BMD SYSTEM COST SENSITIVITIES



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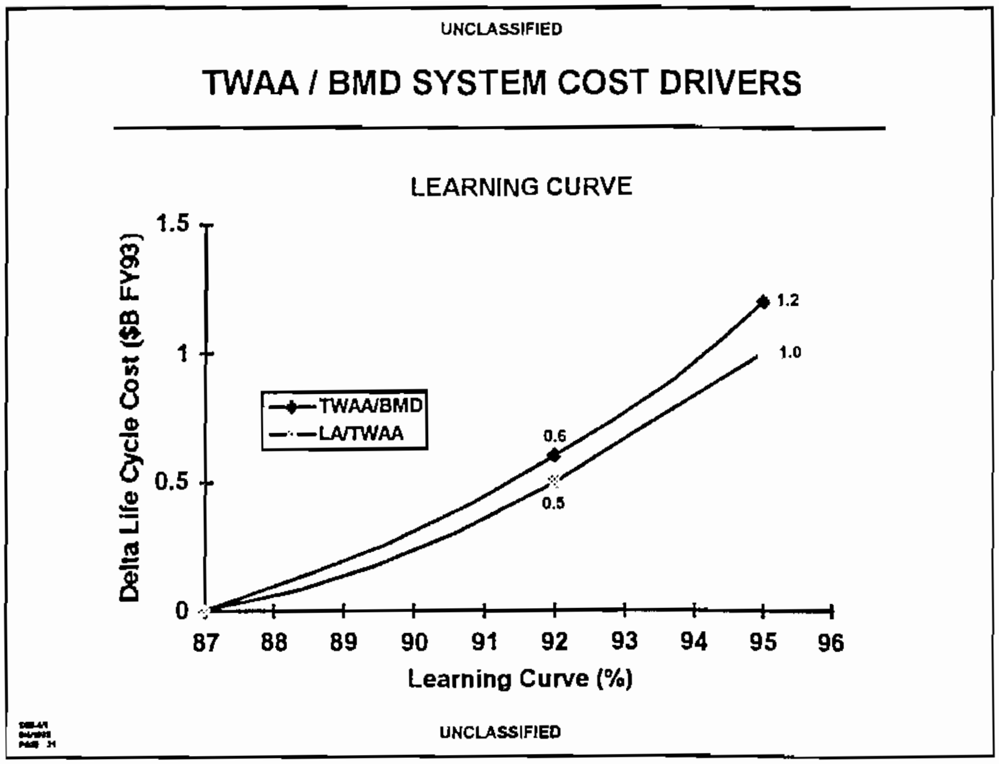
TWAA/BMD System Cost Uncertainty - MMD (U)

(U) Satellite mean mission duration is a significant recurring cost driver for low altitude distributed satellite constellations. MMD affects the number of replenishment satellites that must be purchased over the life of the system. Cost impacts consist primarily of additional production satellites, launch vehicles, and launch operations support.

(U) The TWAA/BMD and LA/TWAA best estimate costs were computed based on a 10+ year design life and 8.5 year mean mission duration (MMD). There is little low altitude satellite design experience for design life and MMD of these durations. To access the cost sensitivity to MMD Life Cycle Cost(LCC) for MMDs of 7 and 6 years were computed. The only other low altitude system currently under development at SMC is the Defense Meteorological Satellite Program (DMSP/BLOCK 6) which has a MMD of 5 years.

(U) MMDs in the range of 7-8.5 years have been achieved for high altitude communications satellites. One of the risks in the DPS^{++} program was assessed to be the difficulty in upgrading the current spinning spacecraft bus with an MMD of 59 months to the 8.5 years used in the best estimate cost. DSP^{++} MMD was varied from 6 to 8.5 years to assess LCC sensitivity. The result was a $2.4 billion range in LCC solely due to the MMD assumption.

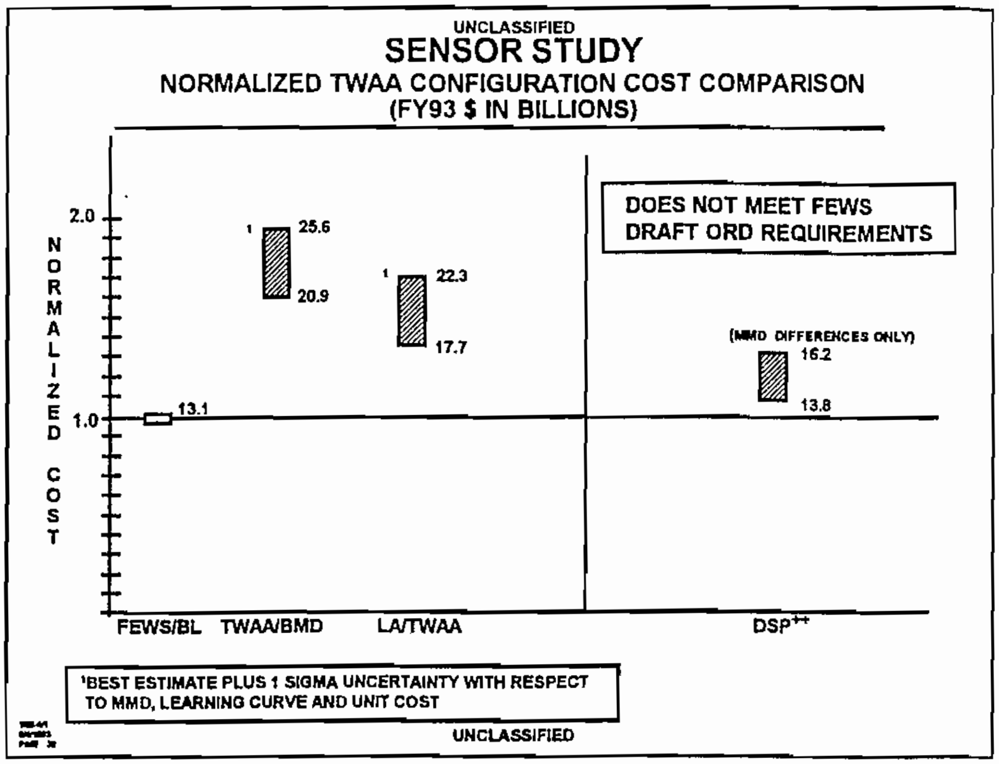


TWAA/BMD System Cost Drivers - Learning Curve (U)

(U) This chart depicts the delta Life Cycle Cost (LCC) to the TWAA/BMD and LA/TWAA programs which would result from changes in the production learning curve assumptions. Economic order quantity, funding, and program stability all affect achievable production efficiency.

(U) A 95% learning curve is typical of a limited production satellite system with significant "hand" tooling like FEWS or DSP. A 92% learning curve represents a limited "realized" benefit learning curve for a 100+ satellite production program. The listed 87% learning curve really represents a 95% learning curve with two 10% step downs: one after the DEM/VAL system development, and the second following completion of low rate initial production (using a 95% learning curve) continuing through production (using a 92%learning curve) completion. The 87% curve was used in developing the low altitude constellation best estimate cost and derives from volume aircraft and missile production program experience.

(U) A $0.6 and $1.2 billion TWAA/BMD LCC increase would be realized if the costed 87% were actually 92% or 95% "respectively". Under similar conditions, the LA/TWAA LCC differentials would be $0.5 and $1.0 billion "respectively".



Sensor Study - Normalized TWAA Configuration Cost Comparison (U)

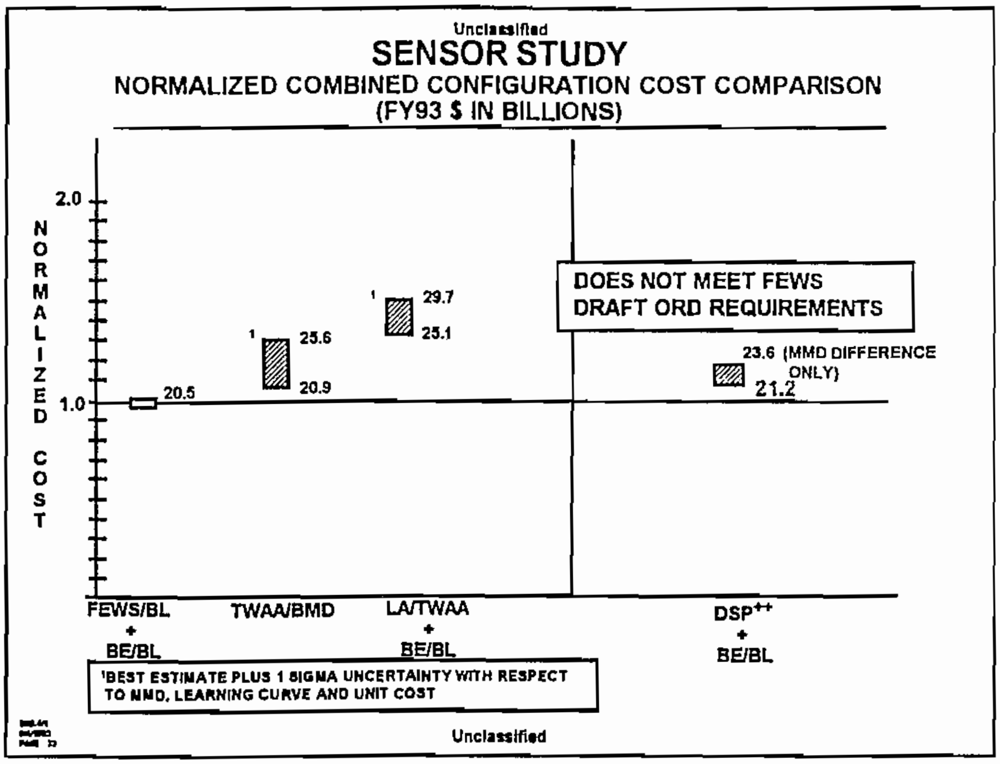
(U) This chart depicts the estimated LCC in constant year (FY93) dollars of the TWAA candidate concepts. Each includes the cost to develop, acquire, launch and operate (10 years) the systems through the year 2015. These cost estimates were developed by SMC cost analysts using subsystem level design and engineering data derived from FEWS, Brilliant Eyes, and DSP contractor designs, and SMC/Aerospace technical and risk evaluations.

(U) The FEWS LCC is a point ($13.1B), consistent with the Milestone I COEA. DSP transition costs have been eliminated and FY91 dollars have been converted to FY93. The other concepts are stated on the same basis. TWAA/BMD and LA/TWAA were assessed to require an additional DSP and launch vehicle for transition (over FEWS baseline) - cost $600 million. TWAA/BMD and LA/TWAA do not carry the NUDET payload in the FEWS baseline - cost to re-host of $1.2 billion is included in the totals.

(U) The cost sensitivity bands for TWAA/BMD and LA/TWAA were computed by root sum square (RSS) combining the effect on LCC of the three sensitivity parameters: T1 cost, MMD and production learning curve. The cost uncertainty for TWAA/BMD and LA/TWAA was computed as $4.7 billion and $4.6 billion, respectively.

(U) The cost sensitivity band for DSP^{++} +BE was computed by considering the effect of MMD (6-8.5 years) on DSP^{++}. Cost sensitivity was computed as $2.4 Billion. Note that the DSP^{++}+ BE concept does not meet the FEWS ORD requirements.

(U) Comparing the costs and cost risk of the candidate concepts, the FEWS concept has a significantly lower cost and cost risk for the TWAA mission.



Sensor Study - Normalized Combined Configuration Cost Comparison (U)

(U TWAA Satellite system configurations life cycle cost (LCC) are shown. These cost were developed by SMC cost analysts using subsystem level design and engineering data derived from FEWS, Brilliant Eyes, and DSP contractor designs, and SMC/Aerospace technical and risk evaluations. These numbers reflect program development, deployment, and 10 years operations, replenishment, and support costs in FY93 constant dollars.

(U) The FEWS + BE baselines (FEWS/BE) number shown represents the program best estimate (CAIG estimate) in FY93 dollars. No engineering or risk evaluations were done against these baselines. This baseline maybe further reduced as a result of the ongoing FEWS/BE integrated architecture analysis.

(U) The TWAA/BMD and LA/TWAA+BE alternatives are shown. The lowest numbers reflect the best estimate ($20.9 and $25.1 billion respectively). The top number reflects a one sigma variance above the best estimate consisting of the root sum square for mean mission duration range (8.5 to 6 yr), learning curve (87% to 95%), and potential subsystem T1 variability between heavy satellite (FEWS) and light satellites (Brilliant Eyes).

(U) DSP^{++} and BE best estimate and one sigma LCC are shown. The DSP^{++} + BE alternative cannot meet the TWAA operational requirements. There is no direct comparability between these two costs because of differences in fidelity of concepts -- DSP^{++} costs were based on a previous COEA "paper" option and lacks similar rigor as the baseline FEWS/BE.

(U) While the FEWS+BE baselines and TWAA/BMD reflect similar best estimate costs. The cost uncertainty could result in a 25% cost differential.

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SENSOR STUDY
OUTLINE

- FEWS AND BRILLIANT EYES (BE) BACKGROUND
- STUDY DESIGN ALTERNATIVES
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OPERATOR PERSPECTIVE
LEGACY OF BSTS/SSTS TO FEWS & BE

DIFFERENT MISSIONS

↓

DIFFERENT IMPLEMENTATIONS

DIFFERENT REQUIREMENTS

↓

DIFFERENT TECHNICAL SOLUTIONS

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OPERATOR PERSPECTIVE
LEGACY OF BSTS/SSTS TO FEWS & BE

(U) The Air Force did not reach its current FEWS and Brilliant Eyes requirements baselines by happenstance. Each mission (TWAA and BMD) responds to different operational and environmental factors: TWAA - global coverage for hot plume detection and attack characterization against a warm earth background; and BMD - warm/cold body fine tracking for weapons application against the cold background of space.

(U) The technical requirements for each are different and have evolved from many years and multiple billions of investment dollars. Comparative alternatives (TWAA/BMD, LA/TWAA, DSP++ plus BE) are less technically and operationally defined than the FEWS and BE baseline system concepts. These alternatives also lack the historical review/verification to which the FEWS and BE systems have been subjected.

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OPERATOR PERSPECTIVE (CONT)
LEGACY

FEWS
- $2B TECHNOLOGY
- TWO AF SUMMITS
- JROC REQS
- CAIG REVIEW
- DAB REVIEW
- SECOND DEM/VAL

BE
- >$1B TECHNOLOGY
- "GPALS" JROC REQS
- CAIG REVIEW
- SECOND DEM/VAL

FEWS SOURCE SELECTION:
- **ALLOWED DISTRIBUTED ARCHITECTURE**
- **ALLOWED "DSP" ARCHITECTURE**
- **GOT NEITHER**

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Operator Perspective: Legacy 2 (U)

(U) This chart represents the historic "audit trail" of the baseline FEWS and BE programs. FEWS and BE have gone through system requirement assessments and other "corporate" reviews. The alternative concepts presented in this study lack similar fidelity and rigor. This points out that the risk of achievement for the TWAA/BMD, LA/TWAA, and DSP^{++} study alternatives is higher than that of the FEWS and BE baseline programs.

(U) It has been noted by senior Air Force leadership that "FEWS is the most highly reviewed and scrubbed of any white or black space program in history."

(U) As a final point on legacy, the possibility of alternatives to a high altitude TWAA approach was left open in the FEWS RFP. No low altitude or DSP variant was bid (implying no contractor-perceived cost advantage).

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OPERATOR PERSPECTIVE (CONT)
PREEMINENCE OF TWAA MISSION

- UNAMBIGUOUS/HIGH CONFIDENCE
- RATIONAL CONSERVATISM
- INCREASED MULTI-POLAR DEPENDENCE ON WARNING
- TWAA IS FOUNDATION FOR BE IMPLEMENTATION

NO OPERATIONAL ADVANTAGE TO COMBINED SINGLE LEO PLATFORM

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...rator Perspectives: Pre-Eminence of TWAA (U)

Historically we have (by cautious intent) built in a degree of conservatism in our ...istic missile attack warning and assessment capability which (1) assures that when ... ...ssile exchange occurs, we know how to respond; and (2) that we do not react to a ... alarm. In the former bi (U.S. and Russia) or tri (add China) strategic ballistic ...sile world this was a difficult task. In today's multi-polar ballistic missile world, our ...A confidence requirements have increased. The proliferating theater ballistic ...sile threat (some 20 world-wide players by the end of the century) has compounded ... complexity ,difficulty, and importance of the TWAA mission.

Our current FEWS (TWAA) and Brilliant Eyes schedules (FEWS lead, BE lag by ... years) are a good match. FEWS "enables" ballistic missile fire control by acting ... ...e surveillance function, and providing the cornerstone for an integrated ...A/ballistic missile defense architecture.

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OPERATOR PERSPECTIVE (CONT)

INCREASED RISK IN SINGLE LEO SYSTEM

- INTEGRATION COMPLEXITY
- SURVIVABILITY
- LOSS OF "ONE" PAYLOAD → REPLACED BY "TWO"
- TW/AA ON BE SATELLITE INHIBITS GRACEFUL GROWTH IN BMD CAPABILITY
- "GPALS" SCHEDULE/PROGRAMMATICS DETERMINE WHEN TW/AA NEEDS ARE MET

RESULTS IN SIGNIFICANTLY HIGHER TECHNICAL, OPERATIONAL AND PROGRAMMATIC RISK THAN BASELINE

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Operator Perspective: Increased Risks (U)

(U) The TWAA/BMD alternative represents significantly increased risk over the other options by tying two complex functions on a single platform. The proposed 1600 km low altitude distributed systems operating region has an inherently more severe radiation operating environment along with greater accessibility by anti-satellite and other weapons. In addition, this lower altitude operating environment results in significantly more frequent eclipse cycling of bus/payloads, translating into increased technical risk.

(U) Another problem is maintaining continuity of operations. Today we do not necessarily replace a satellite when one of its mission capabilities degrades. While a proliferated system degrades gracefully, the issue of replacing these expensive, equally important missions while still possessing significant operational capability creates a cost and replenishment strategy challenge.

(U) A combined platform approach is "all or nothing" with respect to TW/AA. Such an approach significantly limits or eliminates incremental growth in BE BMD capabilities. Another significant point to remember is that a joint TWAA/BMD satellite is subject to the SDIO development schedule and funding, as well as, anti-ballistic missile (ABM) treaty interpretations.

(U) At a higher potential cost, we incur increased technical, schedule and programmatic risk with no increase in military utility vice the baseline FEWS and BE programs.

OPERATOR PERSPECTIVE (CONT'D)
DSP++ LIMITATIONS

- LIMITED TECHNICAL LEGACY
  - COEA " PAPER " OPTION $2B AND 8 YEARS OF EFFORT
- MINIMAL TECHNICAL/OPERATIONAL MERIT
  - NO THREAT GROWTH CAPABILITY NOR DIRECT TO THEATER MESSAGES
  - SIGNIFICANT TECHNICAL ISSUES (COOLING, X-LINKS)
  - SIGNIFICANT TACTICAL THREATS NOT ADDRESSED
- MAY NOT "ENABLE" HAND-OFF TO BRILLIANT EYES
  - POTENTIAL LOSS OF "INTEGRATED" CONSTELLATIONS SAVINGS
  - POTENTIAL LOSS OF SIMPLIFIED BE SENSOR PACKAGE

RESULTS IN LESS CAPABLE, ZERO-GROWTH SYSTEM WITH GREATER TECHNICAL UNCERTAINTY

OPERATOR PERSPECTIVE (CONT'D)
DSP++ LIMITATIONS (U)

(U) DSP++ will require significant changes to the current DSP focal plane, attitude control and ground processing among others. In reality, DSP++ is a completely new satellite. The maturity of the COEA DSP++ "paper" option extracted for this comparison does not compare to the $2B and eight years of effort related to BSTS, AWS,and FEWS. We do not have the same degree of confidence in the COEA DSP++ cost estimate as we do with FEWS.

(U) DSP++ provides minimal technical/operational merit. DSP++ does not have the ability to detect the new missile threats such as dim targets - targets which will comprise a significant portion of the 2005 threat. DSP++ offers no threat growth capability nor direct and timely messages to theater users. Spinning focal plane arrays (such as DSP and DSP++) are difficult to cool due to spacecraft radiator inefficiencies. Crosslinks on a spinner are difficult because the antenna must gimbal on a despinner platform to keep the crosslink pointed to the receiving satellites. These will result in a new bus design - not just an upgrade of the current design.

(U) DSP++ does not provide data quality (resolution accuracy, and timeliness) sufficient to hand off to BE under all operating conditions. With DSP++, BE will be required to maintain a robust surveillance and processing suite which potentially could be reduced.

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SENSOR STUDY
OUTLINE

- FEWS AND BRILLIANT EYES (BE) BACKGROUND
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FINDINGS

- FOR TWAA MISSION FEWS PROVIDES THE LEAST COST OPTION
- FOR THE COMBINED TWAA AND BMD INTERCEPTOR COMMIT MISSIONS, FEWS AND BE STILL PROVIDE THE LEAST COST RISK APPROACH
- EXISTING FEWS AND BE PROGRAMS OFFER BUDGET FLEXIBILITY TO PHASE DEVELOPMENT AND ACQUISITION COSTS

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Findings(U)

(U) For the currently defined TWAA mission requirements (draft Air Force Space Command Operational Requirements Document), the current FEWS system represents the lowest cost and least risk approach.

(U) For the currently defined TWAA and BMD mission requirements (draft Air Force Space Command Operational Requirements Document and U.S. Space Command GPALS/BMC3 Operational Requirements Document) the current FEWS and Brilliant Eyes (BE) programs represent the lowest cost and least risk approach.

(U) The current FEWS and BE programs also provide the best alternative for spreading budget commitments while achieving a rational implementation schedule.

RECOMMENDATIONS

- CONTINUE WITH FEWS AND BRILLIANT EYES PROGRAMS
- COMPLETE TALON SHIELD TO EXPLOIT DSP FOR TACTICAL USE (ONLY NEAR TERM CAPABILITY)
- DSP++ OPTION SHOULD NOT BE PURSUED FURTHER
- USING FEWS AS A BASELINE, EVALUATE ADJUSTMENTS TO BRILLIANT EYES TO REDUCE COST AND INCREASE PERFORMANCE

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Recommendations (U)

(U) Continue with the current FEWS and Brilliant Eyes (BE) programs to achieve a space-based ballistic missile tactical warning/attack assessment and ballistic missile defense capabilities. Field FEWS first and field BE second.

(U) Near term, space-based TWAA supporting the theater commanders-in-chief is needed. Talon Shield represents the only near-term Air Force program designed for providing this capability. We recommend continuation of this program.

(U) DSP++ does not provide significant improvement over the current DSP sensor except in areas of update rate and medium wave infrared sensitivity. Without modification to the BE technical baseline, TWAA military utility for the combined systems against tactical, intermediate and intercontinental range ballistic missiles is not increased significantly. A stabilized platform is necessary to achieve the sensitivity for low intensity targets in any infrared band. Modifying DSP in this manner makes it a FEWS.

(U) There are potential savings to be achieved through system engineering an integrated TWAA/BMD architecture using FEWS and BE. We are currently investigating how to integrate the FEWS and BE programs to optimize system performance against TWAA and BMD requirements.