Review Of The Conclusion And Model Of The SIGINT Mix Study

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26 March 1996

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Executive Summary

The information in this Summary is extracted directly from the complete document. Full reasoning, logic, and evidence can be found in the document itself.

Introduction

As the military prepares for the needs of the early part of the next century, there is little doubt that an understanding of the type and mix of electronic warfare systems is needed. It was the original intent of the SIGINT Mix Study (SMS) to provide just such an objective view. Review of the results of that study surface significant shortcomings in the methodology and application of the model used.

In the first release of the model results, Guardrail/Common Sensor (GR/CS) was isolated from Airborne Reconnaissance Low (ARL) and recommended for elimination. Discussions between LTG Menoher, DCSINT, and Mr. Richard Mosier, SMS sponsor, resulted in the recommendation being changed to "transitioned" with no follow-on platform recommended. Subsequently, the SMS recommended, informally, that the platform be a High Altitude Platform (HAP) capable of flying above enemy Air Defense Artillery (ADA) threat and penetrating enemy air-space. In a preparatory briefing by MG Israel, Director of DARO, he sighted the SMS study in presenting number of platforms needed for the future airborne SIGINT systems-reducing both GR/CS and ARL to zero. Notably no other platforms were so reduced.

Summary Of Issues For SMS

The SMS recommended replacing GR/CS with a yet to be developed replacement system, the HAP. GR/CS's elimination was reasoned within the model by applying power propagation rules that show a signal is easier to detect when close to it than far away. This drove the conclusion to requiring a penetrator rather than a stand-off system. By simply assessing the GR/CS platform against a future SA 10 and SA 12 threat, it was deemed that GR/CS would be unsurvivable driving a need to move to a high altitude platform. Without consideration of critical physics and engineering issues, operational issues, or programmatics (especially any consideration of cost), the study concluded an HAP should replace GR/CS.

TDOA/FDOA using multiple systems is assumed in the HAP scenario to provide precision geo-location. GR/CS is the only system currently doing multiple aircraft TDOA/FDOA. It has provided the baseline for PSTS, the only combined platform TDOA done, to date. Despite this proven and unique track record, the study recommends eliminating GRCS to be replaced with a system not designed.

Because much of the study was done within a B cleared environment, GR/CS personnel had only limited access to add to the discussion or evaluate the technical merit of the model. Subtleties in the physics, fundamental laws not changeable through engineering or expenditure of funds, show that the best point of detection of a signal is frequently not directly above or necessarily close to the source. Engineering constraints such as antenna configurations, their effect on the aerodynamics of a high altitude platform, and the intimate coordination necessary for TDOA/FDOA were not sufficiently addressed in the study. Examination of the modeling effort itself showed that many of these constraints were simply assumed away. Much of the analysis was based on the ELINT part of the spectrum rather than the COMlNT realm of greater interest to the ground commander.

Operational issues were not included in the model but added as follow on analysis. For example, the ADA threat seems to have been critical to the decision to eliminate GR/CS but had no impact on other systems equally susceptible. The greater air campaign was not considered. If the environment is unacceptable to GR/CS, it is equally unacceptable to JSTARS and AWACS, both of which fly in the vicinity of GR/CS. TDOA/FDOA in the proposed HAP replacement requires tasking of systems including national assets by the ground force commander as if they were organic. This is a significant doctrinal change not founded on any specific program; yet, absolutely necessary to accomplish the task. A final and critical shortfall in the model is that the recommendation to eliminate a proven system and replace it with a yet to be designed concept was based on a technical model without consideration of cost. The HAP and its configurations were not fully modeled but their capabilities assumed. Then no further discussion was made of the cost of following this path. Based upon the cost of extending systems already proven through major P31 efforts, the cost must be considered fully, to include support requirements before any recommendation can be made.

Conclusion On The Recommendations And Value Of The SIGINT Mix Study

A SIGINT mix analysis is unquestionably needed to prepare for future threats in a resource constrained environment. This model may provide a base upon which to grow a more mature model which includes critical parameters, both physics and engineering based. But the level of technical resolution in this study does not support the conclusions reached. A lack of rigorous and complete operational review failed to include the response being planned for the threat by the services not just for GR/CS and ARL survivability but other platforms like AWACS and JSTARS. To quickly move to a HAP simply to get above any possible enemy threat is an expensive and incomplete response. While expensive, the model does not examine any of the costs of its conclusions. Both GR/CS and ARL are extremely economical to operate, more so than any other platforms. Yet, they were recommended for elimination in favor of a platform not yet costed or built carrying a SIGINT (and perhaps later IMINT) package still to be funded.

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Reasons For Elimination GR/CS

The study eliminated GR/CS for two basic reasons:

1. GR/CS flies below 60,000 ft making it susceptible to future ADA threats such as SA 10 and SA 12 missiles.
2. Because GR/CS is a stand-off system, it is less capable of detecting and precisely geo-locating enemy systems than a penetrating aircraft.

Reasons For Selecting The HAP To Replace GR/CS

The study required the replacement platform be capable of:

1. Full SIGINT. That is, both COMINT and ELINT.
2. Precise geo-location be possible in both modes.
3. Platforms at all altitudes to include non-air-breathers are expected to be used in combination for precision geo-location.
4. The best possible signal detection (sensitivity).
5. Avoidance of ADA threat.

A HAP would fulfill all these requirements while not putting the life of a pilot at risk according to the study. The assumed platform (there is only a proposed ACTD for a HAP in December 1996) would have a yet to be developed SIGINT package (there appears to be a $60M set-aside in ARPA for development of a new SIGINT package for this future platform).

Method Of-Evaluation In This Paper

To refute the conclusions of the model, this paper begins with a look at the fundamental physics applied to the model. Physics is, essentially, God's rules and cannot be engineered around. They must be contended with at face value to create a working system or to appreciate the accuracy of a model. Once these foundational shortcomings are identified, the challenges of engineering the HAP and SIGINT package assumed as a replacement are discussed and contrasted with the currently operational capabilities of GR/CS and ARL. Those operational deployment and use issues of most concern to the PM are identified next leaving an even more robust evaluation of this area to the user community (an effort initiated by LTG Menoher and the Fort Huachuca TRADOC Systems Manager (TSM)). Finally, a brief review of key programmatic issues are addressed and followed with conclusions.

Physics Bind Issues Of The SMS

The core issue raised by the SMS between GR/CS and a penetrating HAP is that the latter would be approximately 50,000 feet from a signal source while the former is as much as several hundred kilometers from it, reducing its ability to detect signal. Signal power is inversely proportional to the distance between the source and the detector. That is, the farther away, the harder it is to see a signal. This is unquestionably true and intuitively obvious to anyone realizing a light at night works the same way. It appears much brighter close-up than far away. Faint lights can only be detected either close to the source or with sufficient amplification.

The model uses this fact to justify the inerrancy of overflight providing greater signal sensitivity than at stand off. Attempting to apply this law to real antenna configurations constrained by other parameters such as the structure of the airframe itself do not appear to have been sufficiently addressed in the model.

Antenna Power: To detect a particular frequency, an antenna must be proportional to one-half the wavelength to be detected. While this sounds technical, it implies the best antenna to detect HF (<30MHz) should be about 5 meters long. This regime is of importance to the ground force commander since most military communications are done by radios in this regime (COMINT). Not even GR/CS can accommodate this antenna and must reduce its size. The smaller the antenna, the less power it can detect. A HAP would then need to accommodate antennae similar to that of GR/CS or decrease detection power, the original reason to overfly. In turn, it would be a significantly greater problem to fly at the 50,000 to 60,000 foot level for long durations than it has been for GR/CS. If only ELINT signals are assumed (>2GHz. for the High Band Prototype, HBP), much smaller antennas can be used.

Antenna Arrays: Precise geo-location via Direction Of Arrival (DOA) requires at least 3 (we use 6 baselines for COMINT & 4 for ELINT) antennae placed in a known configuration separated by multiple wavelengths. This is the reason that GR/CS has a series of similar antennae placed at different locations on the airframe. As a plane wave front arrives at the aircraft, it hits one antenna before the next and before the last. These small time differences (the waves are traveling at the speed of light) are very accurately measured through interferometry, a technique of combining the signal to produce a measure of the difference known as phase. By knowing the phase between different pair, a Direction Of Arrival can be calculated. The accuracy of the DOA is very dependent on the accuracy of the geometry of the antenna array and its sizing to the frequency. Since the HAP must look down, the antenna array must also point down. Unlike GR/CS which looks horizontally with the antenna array placed horizontally on its wings, it does not have a large vertical surface on which to mount the antenna. It would become very difficult to geo-locate signals below the aircraft for those frequencies of most value to COMINT users.

Transmitting Antenna Are Not Perfect Omni-Directional Antenna: While the study accounted for antenna gain (the improvement a particular antenna has to send or receive a signal based on its physical geometry), it appears to have disregarded the actual radiation pattern. The most omni-directional military antennae in the COMINT regime are 'whip" or dipole antennae. The radiation pattern for dipoles looks similar to a doughnut with the whip pointing up through the middle. It is used in the upright position in order to send its power out along the ground rather than up so increased range is gained. The result is, very little energy goes up. A visual spectrum analogy is a light stick held vertically. It is brighter when viewed from the side than the top. The result is that the best place to detect such signals is unquestionably at a distance from the source rather than above. Signals higher in the spectrum have shorter wavelength making it easier to build directional antenna. Since these antennae link, for the most part, points on the ground, their detectable energy tends to be horizontal rather than vertical. Flying over them requires greater sensitivity to detect "leakage" known as sidelobes. Once in the ELINT part of the spectrum, signals are often so collimated they are called beams. These radar beams are normally oriented off at an angle since their objective is to detect aircraft at a distance. While they would be very easy to detect if pointed at a high altitude penetrator, such a craft is likely to only see sidelobes.

Atmospheric Transmissivity And Reflectivity: Power of a signal is not only decreased by distance, it is also decreased by the ability of the atmosphere to allow it to pass through, transmissivity. This transmissivity is different horizontally than it is vertically. In the HF part of the spectrum, the charged particles of the ionosphere make it look as if the earth is encased in silver mirror. The earth surface looks similar. As a result, HF waves bounce between the ionosphere and ground as if traveling in a wave guide or fiber optic cable. This gives this COMINT frequency one of its greatest attributes, the ability to travel long distances. It also implies that little of it will escape into space. Without some exotic calculations it would be difficult to assess any added value or deleterious effect of being close or far from the source. On the other hand, a significant assumption in the SMS is that precision geo-location can be accomplished using multiple vehicles at various altitudes. Should anyone of these be outside the ionosphere it will not likely to detect HF signals. While significant in the COMNT regime this argument has little value in the ELINT spectrum. The SMS did not even consider the HF signal threat much less the environmental factors.

Near Field, Far Field Effects: All direction finding algorithms assume the detected signal is a "well behaved wave." That is, the detector is at a point where the wave is so far from the source that it acts like a plane wave no matter how curvy it was at the source. This is known as the Far Field. Recall the doughnut shaped radiance pattern described above for a dipole antenna. If the detector is far away from the antenna, the signal wave front has a chance to become less curved. Near the antenna, there is always a great deal of shape to the surface because of the source being present. This is known as the Near Field. To avoid the Near Field, which makes it very difficult to determine the source of a signal without changing the algorithms (many of which are already built in software and sophisticated hardware), the detector must be placed a distance from the source. Detecting signals too close to the source can actually make it more difficult to resolve a precise location. If the algorithm requires detection from some sensors in the Near Field and others in the Far Field regime, calculations become even more complex as suggested by the multiple altitude and platform geo-location assumptions. Again, this effect encourages not flying over the target to detect it and is most dominant in the lower end of the COMINT portion of the spectrum. Because Near and Far Fields are based on the wavelength, short wavelength ELINT signals quickly appear well behaved if detectable any reasonable distance from the source.

Polarization And Aperture: If a detector is close to a source but in the Far Field regime (see above), such as would be the case for a high altitude penetrator, the wave fronts will be coming up to meet the antenna array from below. It hits the vertical (it is as valid if a horizontal antenna is assumed) at an angle. The antenna appears shorter than it really is. Since antennae detect best when properly sized to the wavelength, the antenna efficiency or gain is decreased. This effect is easy to understand if you hold a pencil straight down and "eyeball" its length. Raising it directly up, it will appear to shrink. If the same pencil is taken a great distance from the observer, raising it an equal distance will have less effect on the apparent starting size. This consistent apparent size allows consistent antenna performance and is critical to many of the algorithms used for precision geo-location. Again, power is not the only consideration in properly detecting signals.

Co-Channel Rejection: Anyone who has flown at night knows it is easier to detect many signals(lights) from up high than it is from down low. However, it is also more difficult to sort through the many signals. The more you see at once, the more to sort through. This greatly increases the computing power necessary to resolve geo-location. If the detector is close to a very strong signal source, it becomes very difficult to detect other sources of less power even if not co-located with the strong source. Headlights in a person's eyes on a dark road make it difficult to see the reflection of one's own headlights on roadside reflectors. The farther away the bright source, the easier it is to see the weaker signals. Therefore, flying over a source can actually decrease your ability to see many of the available signals detectable at a distance.

Signal Detection: The model made each analysis based on detection of a single signal source. While the model examined a high density signal environment, it disregarded a number of significant yet subtle effects. If many signals are present concurrently and they have varying power levels they can cause the "tuners" to allow some bleed over, confusing further processing. This is somewhat akin to when a portable radio is timed to one frequency and as you travel begins to pick up stronger but different frequency signals. Design of the receiver, especially a digital receiver, is critical to ensure detection of signals of interest and rejection of noise due to high dynamic range. For an accurate comparison of the SIGINT package on the HAP with that of GR/CS, the specifics of the system design would be necessary.

Summary: In a simplistic way, the power measured at a detecting antenna of any gain from a radiating antenna of any gain will be best when the two antennae are close together. However, physical limits to antenna size, placement, and orientation; frequency of interest; practical radiating patterns and directionality of signals; reasonable algorithm assumptions of well behaved signals; and the ability to discern one signal from another demand reconsideration of the best location for detection. A high flying penetrator may not be the best solution from a physical standpoint. Based on the insight into the model on hand, today, most of these considerations were not included. This leaves the fundamental conclusion for a HAP as suspect.

<u>Engineering Based Issues Of SMS:</u>

The model determines that the best method of precise geo-location is Time Difference Of Arrival (TDOA) and Differential Doppler (aka. FDOA). This method requires multiple platforms and is well proven on GR/CS, the only platform currently capable of performing it. However, TDOA/FDOA is a computing intensive process, which requires a way of reducing the possible solutions to a few before attempting a final determination. Computation time, while still extensive, has been reduced on GR/CS by first queuing the TDOA/FDOA system with the DOA system described above. There is very tight coupling between the DOA and TDOA/FDOA systems and much work has gone into the MMI and tasking methodology. None of these factors were evaluated in the SMS. A number of additional engineering solutions and possible approaches highlight the difficulties inherent in attempting a new systems approach to a solved problem.

Current Systems Value Is Ignored: GR/CS is the only multi-platform precision SIGINT system currently fielded and has been using TDOA/FDOA for over 5 years. This amounts to not just a proven system, but significant operational insight. Multi-platform DOA is used to quickly map out the battlespace and sort out the high payoff targets and reduce the area of interest for the CHAALS or CHALS-X TDOA/FDOA system. Based on the operator's desires, all aircraft (no less than 2 and preferably 3) look at the same signal at the same time sending very precisely timed samples of the signal to the IPF for processing. Timing between the aircraft is carefully controlled and both GPS and INS provide highly accurate location, direction, orientation, and speed of each aircraft. The long baselines (>70km per plane and >140km for the system) provide a significant source of accuracy not available through single aircraft DOA. Thus, multiple aircraft are required. Computations done in the IPF then combine these inputs to create intersections resulting in accuracies of location better than the ground based weapons which can reach to the targets. Actual values are classified. Fundamentally, if the Army can shoot it; from mortars to ATACMs, GR/CS can provide a target location with more precision than the weapon system can hit. System 2, currently in production, will be able to do all computation on the platforms and conduct TDOA/FDOA in all but single aircraft modes. By recommending the elimination of GR/CS, the study has recommended the elimination of the only system with a demonstrated TDOA/FDOA capability. GR/CS is still the only DoD system with an integrated INS/GPS navigation system and significant work has gone into the Kalman filtering needed for this process.

Must Have 3 Aircraft Overflight TDOA/FDOA: For each pair of detecting systems, DOA does not provide a point of origin but a line along which the transmitting system could be. To get an unambiguous point of origin requires three aircraft, or that the two platforms fly along a baseline to resolve the ambiguity. This allows 3 different possible pairings and a clearly resolved intersection point. FDOA adds information to the equation from the Doppler shift in the signal received at each aircraft. The result of these computations is an oval encircling both aircraft in the pair providing the signal. It is possible to do precision geo-location with only two aircraft as long as both aircraft can provide both TDOA and FDOA input. The result is a line somewhere between the two planes intersecting an oval around both of them. Clearly, there will be two intersections in this case. Under normal flying conditions, one intersection will be disregarded because it will be in the rear area of the friendly forces while the other will be in enemy or target area. A HAP will either have to fly in pairs ensuring survivability of both and a carefully managed flying pattern or link to other systems. In either case, two penetrating aircraft alone will be unable to disregard both points of intersection since they will likely fall within the threat area. Three aircraft will always be needed. This means more high cost systems will have to be put directly in harm's way to obtain the same information GR/CS can already produce.

Current PSTS Results Enhance GRCS: GR/CS was able to combine its data with that of several other national systems in a non-real-time TDOA experiment. A simplistic ELINT emitter was positioned to allow detection for the experiment and was detected from several platforms (specifics are classified). The data was sent to a computing facility using a modified GR/CS TDOA computer and, after computation time, it provided accuracy on the order of the GR/CS alone. However, neither collector was operated in its normal mode for this operation and the process does not provide the throughput and robustness of the GR/CS system operating alone. Again, GR/CS, the system proposed for elimination by the study, is the only system currently capable of this effort.

Co-Channel Interference Continues To Be A Problem: For TDOA/FDOA to work, all detecting receivers must be looking for the same signal at the same time. The signal must be detected and its sampled attributes passed to the computer to make the comparisons necessary to get the TDOA/FDOA position. If there are more than one signal at the detection frequency, the computer must sort out by waveform characteristics which information to combine with that of the other aircraft. The more signals seen by an sensor at once, the more difficult TDOA/FDOA is to determine. Therefore, a HAP will have more difficulty computing TDOA/FDOA because it can see a great deal more than a low flyer. It is not impossible but will likely require more computational capability or more robust communications with the ground station. Most likely, even under the best of circumstances, a HAP will result in slower precision fixes than for a lower flying system.

Antenna Forms Do Not Resolve The DOA Issue For HAP: Dipole style antennas are used on GR/CS and ARL because of their inherent gain and ability to detect signal well in a plain perpendicular to their axis (horizontally on GRCS). These can be placed in an array (see Physics above) to perform DOA. There are other antenna configurations which provide other possible methods of doing DOA but which have their own inherent limitations. Spinning Dish antenna show the greatest signal strength when oriented toward the signal. By knowing the position of the aircraft and the orientation of the dish with sufficient accuracy, a line of bearing can be obtained. Multiple lines of bearing over a course of flight can give intersections which amount to DOA. Two problem with this method are that a spinning dish is an awkward device to fly with (especially when it must be extremely large, proportional to the wavelength for COMINT) and single plane DOA assumes the source stays detectable for long periods of time. Amplitude arrays work similar to conventional DOA arrays and bear the same constraints on the platforms. Many dipoles must be in place, the method of detection changes. Finally, conformal phased arrays provide some interesting new possibilities. However, like all other antennae, each patch must be proportional to the wavelength. While not a significant problem for ELINT frequencies, a 50 meter patch would cover any single wing and several would be needed.

Wide Band Detection Requires Increased Computation: To enhance platform flexibility, a JASS like payload was considered for the HAP using wide bandwidth receivers. While this makes good sense in a number of architectures, it is important to realize that this added flexibility comes at the cost of required added computational capability. To place such a system on a HAP would require it to carry the weight of added computers or pass the data via down-link to a ground processing facility. This may, again, impact the viability of the airframe and its performance, tethered or untethered.

The Best COMINT Computers Are Soldiers: While many Proforma and ELINT signals can be detected and classified by computer, only a combination of the human mind and ears can discern intent from an intercepted COMINT signal. No matter how deep or high the HAP flies, it must have a way to return a COMINT signal to the IPF or point of analysis. A HAP cannot, then, fly untethered without loosing much of its COMINT capabilities. While there are other methods to provide the signal to the ground than simple tethering, all require the involvement of assets not normally available. Ground commanders require COMINT as much as ELINT. The proposed HAP does not appear to have included the subtleties of tether in the modeling and certainly not in the cost.

Cooling Of Electronics Greatly Increases Complexity And Cost: Electronics generate heat which can cause self destruction. Systems like GR/CS use the same climate controls on the aircraft to cool the equipment that accommodate the crew. A HAP may not need such a crew comfort zone. If it was designed as such, it would greatly increase the weight, cost, and complexity of the electronics. Since most systems including much of the U2 payloads, all GR/CS and ARL, and the JASS payloads all require air cooling, either the HASP must be designed to accommodate the electronics or vica versa. Much of what is already developed would be of little value. The proposed HAP platform, unproven, would be adding new, unproven, electronics to replace an upgradable and enhancable, fully proven system, GRCS/ARL/ACS.

Summary: Despite the cursory information on modeling, it has become clear that significant engineering realities have been, in many cases, not included. Precision TDOA/FDOA requires DOA queuing for timely response. This dictates inclusion of antenna arrays on the platform which must be oriented perpendicular to the wing orientation in order to look down. There is limited vertical real estate upon which to mount these antennae. What's more, dipole style antenna, needed for the COMINT regime, have a significant impact on the avionics characteristics of a platform. GR/CS platforms have their duration and ceiling reduced due to them. There is no reason to assume the effect will be anything but enhanced when trying to fly at 60,000 ft.

<u>Operationally Based Issues of SMS</u>

Operational considerations do not appear to have been fully considered in the model. For example, despite the fact that the Rivet Joint and EP3 have similar but lesser capabilities than GR/CS, they were retained in the final force mix. The ES-3 was retained to allow the Navy to have organic “blue water" coverage and the RJ because "the air battle goes so fast". GR/CS was not seen as necessary because there is sufficient time to process any signals and get it back to commanders on the ground because the "ground battle is a fairly slow process." These comments alone show the lack of understanding of the tenor and tempo of ground combat.

ADA Susceptibility: GR/CS and ARL susceptibility to SA 10 and SA 12 threats was the cornerstone of the argument to eliminate them from the system. While it is true that they are susceptible to the threats, they are no less so than many of the retained systems. Rivet Joint, EP3, ES3, all retained by the study, fly at altitudes similar to Army systems. Their survivability will require stand-off as well. GR/CS normally flies in the same vicinity as JSTARS and AWACS, two targets an enemy would likely pursue with more vigor than an RC12. Discussions made it clear that the entire air campaign was not considered in the analysis. In fact, constraints of the ADA threat were not uniformly applied. Had it been so, many other platforms would have to become HAPs as well (JSTARS, AWACS).

TAC Air Threat: No mention of TAC Air threat analysis was mentioned in any briefing. This threat would appear to be a greater threat to overflying aircraft than stand-off. Deep penetrating HAPs would not likely fly with protective cover. Even if they could fly above an ADA threat, they could be reached by many enemy threat aircraft. This would require they become extremely stealthy, a significant cost driver, or inexpensive. SIGINT system are inherently cutting edge technology and expensive even with the maximum use of COTS products. Continuous loss of systems, alluded to as acceptable in the study, would not only be very expensive, but provide an enemy the opportunity to recover and possibly reverse engineer our electronic warfare systems.

Tasking: GR/CS, ARL and ACS all can be directly tasked by the field commander in real time. There are no requirements for bureaucratic mission planning as in the application of TAC Air. Changing priorities is accomplished directly by the Corps or ground force commander. Recall from the above discussion that precision geo-location via TDOA/FDOA require multiple platforms working together. The SMS depends heavily on the combined use of air and non-air breathing assets to accomplish this. This means for a simple TDOA/FDOA, the ground force commander would have to be able to retask national assets in real time to equal the current capabilities of GR/CS. This appears an unlikely scenario without extensive changes in methods of operations of both DoD and non-DoD agencies. What's more, there are, in a manner of speaking, a finite number of retaskings possible in a single national system.

Platform Ownership: The SMS did not recommend ownership of the HAP. However, a Tier II+ style platform fits more in the mold of a Predator style UAV than those to be in the hands of division and below. It appears likely, then, that another service (Air Force) would have to provide the platforms. This would mean that the ground force commander no longer has organic aerial platform SIGINT. It must be incorporated in planning as with other Air Force systems. It is reasonable to argue that the employment model is more aligned with that of JSTARS or AWACS than simple UAVs due to payload costs and the number of platforms likely to exist (there are only 3 deployed GR/CS sets and 6 total ARL aircraft requiring careful management and tracking at DA level). A further concern would be that the platform would be tailored to suit the need of the developing service. COMINT is far more critical to a ground commander than ELINT in general. On the other hand, ELINT is of greater interest to the Air Force and Navy because of the type of threats they must contend with. GR/CS has been tailored to fulfill the ground commander's needs. There is no assurance that such refinement would continue in a non-Army HAP.

Employment Threshold: The model assumed the ground commander would always have the HAP available. Assuming the cost of the SIGINT package to be on the order of those in current systems and an expensive high altitude UAV, there will likely be a limited number of systems available (as described for GR/CS and ARL above). If it is further assumed that the platform is under the control of another service, it would have to be tasked. At first blush, this seems parallel to what is planned for the use of UAVs. However, there are two significant differences which will likely limit the availability of the systems. First, the cost and number would likely be more in line with JSTARS or AWACS than a simple UAV platform (there is no way to precisely state this since the model included no cost analysis). Second, precision geo-location requires use of national assets which would have to be tasked in support of the ground commander for the system to work. There are a few of these systems and they are carefully managed at a level above even Corps. Ground commanders are engaged in missions which span the spectrum from support of peacetime operations (i.e. ARL support of disaster relief) to continuous monitoring of threat areas (GR/CS and ARL-MTI in Korea) to moderate threat environments (GR/CS and ARL in support of Bosnia) to high threat (GR/CS in Desert Storm). At what level this HAP and its requisite supplements would be committed has not been addressed leaving the ground commander without a guarantee of any aerial SIGINT until an undefined level of conflict is reached!

Communication Links Are Critical And Assumed: As discussed above, to do TDOA/FDOA requires multiple platforms with guaranteed and sufficient communications links. While it appeared some communication degradation was included in the study, its specific effect wasn't described. Clearly, communication pipes for a system communicating between many different platforms, from air breathers to national assets, is extremely complicated. To conduct the PSTS exercises required specialized communications links and temporary downgrading of certain information that would not normally be available for tactical operations. This can be automated but at great expense and loss of legacy investments. Adding to the complexity is the need for robust throughput for COMINT. While a great deal of ELINT processing can be moved to the aerial platform as is being done on System 2, COMINT requires the human ears and brain to sort through. Since the HAP is unmanned, it must send the signal to a ground station. As discussed earlier, this will limit the platform's ability to act autonomously. There are a number of possible alternatives to include use of systems similar to the Direct Air to Satellite Relay (DASR) mode being developed for System 2, but no cost or programmatic impact were included in the model.

Dissemination And Latency: Dissemination to the appropriate level is assumed in the model. This is one of the most difficult parts of a complete SIGINT system. Once intelligence is discerned, it must be disseminated without latency to the correct command to act. While not necessarily a unique problem to a multi-platform HAP and other assets the system may have unique difficulties, especially with security constraints of national assets. It should be included in a thorough analysis before elimination of a functional platform is made.

Deployment: The model criticized GR/CS for its lack of mobility and large support requirements. Mobility limitations are rooted in the use of propeller driven aircraft and the need for an Integrated Processing Facility (IPF). By agreement, the Army has been limited to propeller or turbo-prop aircraft. These aircraft have shorter duration and travel slower that corresponding commercial jet aircraft. ARL uses the Dash-7 to provide increased lift and duration but at a reduced altitude. In summary, the deployment limitation of current Army aircraft is rooted in platform selection rather than inherent capabilities economically available commercially. GR/CS must have an IPF to provide the robust processing of COMINT with a human in the loop. The PM has recognized the need to make the IPF more mobile and scaleable. Introduction of a JASA compliant FDDI LAN in the IPF upon fielding of System 1 laid the foundation for doing so. In a first effort, a 2 van configuration was used (half the size of a standard IPF). Subsequently, a repeater capability allowed the IPF of System 1 to remain in place while only a small van went forward to provide a satellite relay terminal. This relay has been extended and sized to fit into a HUMMV shelter. Recently, as part of the PSTS efforts, funding was obtained to house not just a relay but the complete IPF electronics in two portable HUMMV shelters. A projected next step is to move the both the transmission and computer systems into rackmounts which fit in a single aircraft similar to that of an ARL. This and the

DASR System 2 aircraft will allow full self-deployment for a limited period. The HAP was assumed to be self deployable by being pre-positioned at critical sights such as Diego Garcia and having sufficient reach to deploy to any theater of operation. This appears simplistic at best and will impact operational deployability. The system more closely parallels use of B52s than organic SIGINT.

Support Structure: The model assumes sufficient support structure for the HAP.

Summary: A technically perfect system is useless without proper doctrinal application. GR/CS has supported the ground commander for 25 years and refined its operational integration extensively. ARL has followed suit providing timely support of a broad spectrum of mission needs. No realistic operational analysis was included in the model. Only the effect of future ADA systems, unchallenged in the context of a complete aerial campaign, were examined and then incompletely. This operational analysis justified for the purpose of the model, elimination of GR/CS and ARL because of susceptibility to SAMs driving a move to HAPs. Stand-off was discounted on the basis of a need to be close to detect signals without consideration of the physics and engineering discussed above. Only a HAP penetrator would suffice by these constraints. Despite the same threat to other similar platforms, RJ, JSTARS, EP3, AWACS, the only platform deemed unnecessary by this analysis was GR/CS. Many other areas of operational concern to the ground commander such as ease of tasking (to include national assets) was assumed fully in line with any mission need.

<u>Programmatically Based Issues Of SMS</u>

Fundamentally, no programmatics were considered in the model. The model itself focused on a limited number of battle types from the 2 MRC model with the primary focus of the model being on technical issues. This left very significant issues unaddressed.

No Cost Analysis Was Conducted: Although costing data was submitted, no cost analysis was done. The fully functional and proven GR/CS was recommended to be eliminated and replaced with an HAP integrated with other platforms without consideration of the expense of building a completely new system. Of all the systems, GR/CS is least expensive to operate (about $600.00 per hour or a full expense of $1.7M per aircraft) compared with some systems retained (Rivet Joint -$15M per year per aircraft). No figures have been given for development or procurement of either the platform or SIGINT package for the HAP. No figures were included for aligning the other systems into a coherent processing capability in order to do dissimilar multiple platform TDOA/FDOA.

No Consideration Was Made Of Sunk Costs To Include Software: Modern SIGINT systems are very dependent upon software. GR/CS System 2 production costs were nearly half the expense of the system despite over $50M in reuse software. As with hardware, this cost was not considered in the recommendations!

No Risk Assessment Was Made: It was simply assumed that whatever fit in the model as the HAP could be built in time for replacement of GR/CS and that all other systems necessary for cooperative TDOA/FDOA could be modified.

No Modeling Of The HAP Was Run: At the last point of technical review (GR/CS was excluded from most sessions because of a lack of "B" clearance billets), no modeling of the HAP was done. It was assumed to be able to do whatever was desired as a replacement for a real system which had to contend with whatever real limitations were included in the model.

Summary: It is easy to assume a system which fulfills all the users possible needs. It is far more difficult to design, build, budget, allocate, and deliver such a system.

Summary Of Issues For SMS

The SMS recommended replacing GR/CS with a yet to be developed replacement system, the HAP. GR/CS's elimination was reasoned within the model by applying power propagation rules that show a signal is easier to detect when close to it than far away. This drove the conclusion to requiring a penetrator rather than a stand-off system. By simply assessing the GR/CS platform against a future SA 10 and SA 12 threat it was deemed that GR/CS would be unsurvivable driving a need to move to a high altitude platform. Without consideration of critical physics and engineering issues, operational issues, or programmatics (especially any consideration of cost), the study concluded an HAP should replace GR/CS.

TDOA/FDOA using multiple systems is assumed in the HAP scenario to provide precision geo-location. GR/CS is the only system currently doing multiple aircraft TDOA/FDOA. It has provided the baseline for PSTS, the only combined platform TDOA/FDOA done, to date. Despite this proven and unique track record, the study recommends eliminating GR/CS to be replaced with a system not designed.

Because much of the study was done within a B cleared environment, GR/CS personnel had only limited access to add to the discussion or evaluate the technical merit of the model. Subtleties in the physics, fundamental laws not changeable through engineering or expenditure of funds, show that the best point of detection of a signal is frequently not directly above or necessarily close to the source. Engineering constraints such as antenna configurations, their effect on the aerodynamics of a high altitude platform, and the intimate coordination necessary for TDOA/FDOA were not sufficiently addressed in the study. Examination of the modeling effort itself showed that many of these constraints were simply assumed away. Much of the analysis was based on the ELINT part of the spectrum rather than the COMINT realm of greater interest to the ground commander.

Operational issues were not included in the model but added as follow on analysis. For example, the ADA threat seems to have been critical to the decision to eliminate GR/CS but had no impact on other systems equally susceptible. The greater air campaign was not considered. If the environment is unacceptable to GR/CS, it is equally unacceptable to JSTARS and AWACS, both of which fly in the vicinity of GR/CS. TDOA/FDOA in the proposed HAP replacement requires tasking of systems including national assets by the ground force commander as if they were organic. This is a significant doctrinal change not founded on any specific program, yet, absolutely necessary to accomplish the task.

A final and critical shortfall in the model is that the recommendation to eliminate a proven system and replace it with a yet to be designed concept was based on a technical model with no consideration of cost. The HAP and its configurations were not fully modeled but their capabilities assumed. Then no further discussion was made of the cost of following this path. Based upon the cost of extending systems already proven through major P31 efforts, the cost must be considered fully, to include support requirements before any recommendation be made.

Conclusion On The Recommendations And Value Of The SIGINT Mix Study

A SIGINT mix analysis is unquestionably needed to prepare for future threats in a resource constrained environment, however this study does not tell the entire story. The model may provide a base upon which to grow a more mature model which includes critical parameters, both physics and engineering based. But the level of technical resolution in this study does not support the drastic conclusions reached. A lack of rigorous and complete operational review failed to include the response being planned for the threat by the services not just for GR/CS and ARL survivability but other platforms like AWACS and J-STARS. To quickly move to a HAP simply to get above any possible enemy threat is an expensive and incomplete response. While expensive, the model does not examine any of the costs of its conclusions. Both GR/CS and ARL are extremely economical to operate, more so than any other platforms. Yet they were recommended for elimination in favor of a platform not yet costed or built carrying a SIGINT (and perhaps later IMINT) package still to be funded.

Caveat

Aerial Common Sensor (ACS) is a disciplined migration of the best of both GR/CS and ARL toward a coherent system of systems. An objective approach is being taken to examine what exactly will fulfill the user's needs from both a platform and sensor perspective. Between these two programs, the Army can literally detect "from DC to light". It is gaining a great deal of insight into the operational issues and their impact on the most sensible selection of platform or platforms, sensor packages, and remote capabilities (UAV, etc.). What's more, these systems are not "ether-ware”, they exists and can be evaluated. Both programs are characterized by a continuous process of product improvement. In examining alternative platforms, the focus has been on commercial products because of the airframe cost and because, to date, these planes have been able to meet the user's needs. Consideration could be extended to more than propeller driven aircraft if the restriction to them was lifted.