Motorola's Debris Protection Practices

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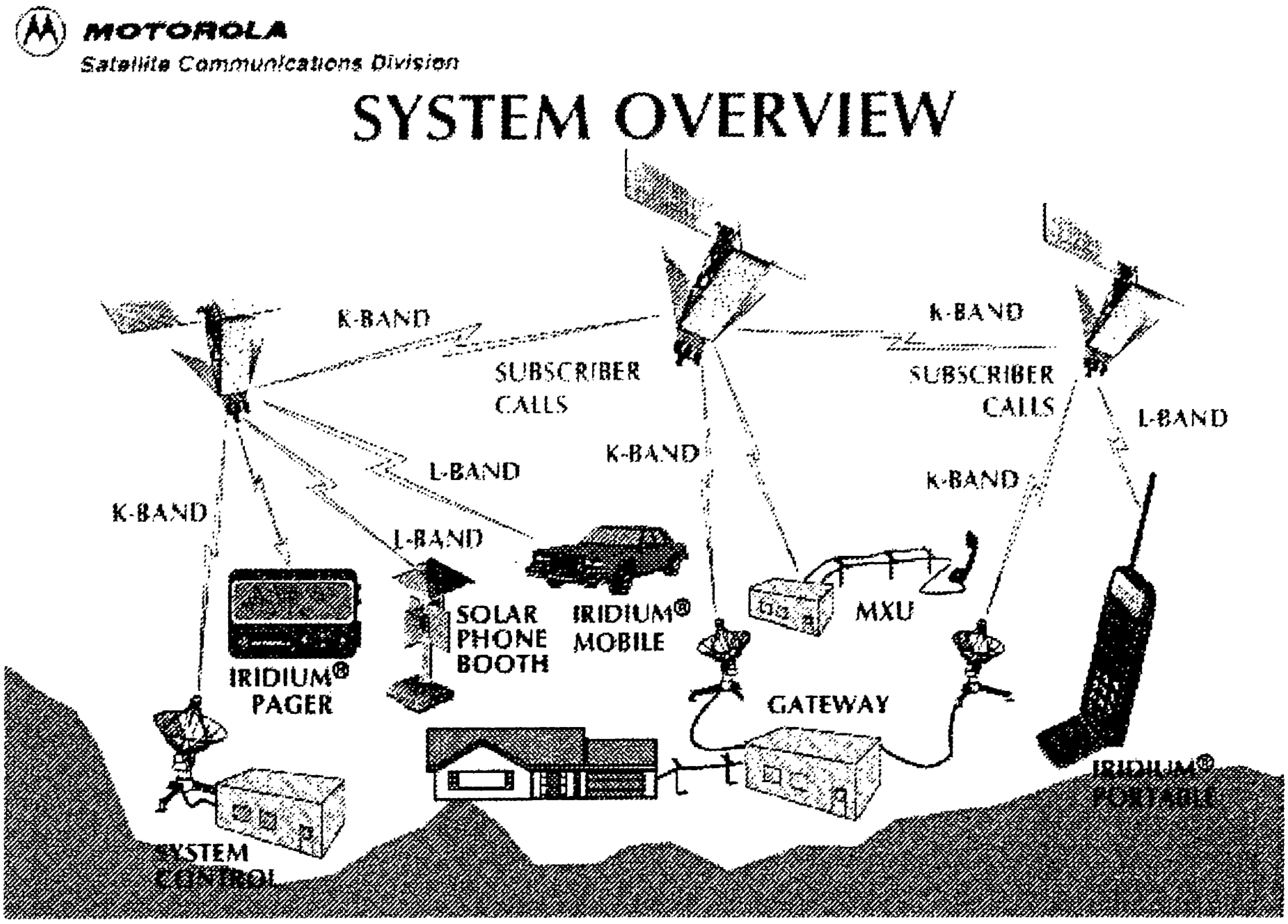
1. INTRODUCTION

Vice President Dan Quail at the 1993 World Space Congress said "It's never too early to start worrying about space debris". This paper will attempt to persuade readers that this notion is the key to effective, including "cost effective", debris mitigation. This is how we've done it at Motorola.



2. DISCUSSION

At the time of the spark of an idea for a satellite or satellites to perform some function, the engineer (or who ever had the spark) needs to address debris mitigation. The candidate orbits should be evaluated for collision risk at the earliest opportunity. This can be done with in house expertise or by any of several qualified sub-contractors. Throughout the process of defining and refining the orbit, this collision risk should be assessed.

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The "debris mitigation" knowledgeable engineer or subcontractor should maintain active involvement in the concept definition phase. Here the basic tenets of mitigation should become more formal. NASA has published the "NASA Safety Standard - Guideliens and Assessment Procedures for Limiting Orbital Debris" which contains 7 areas of interest along with guidelines for assessing each and even includes software to facilitate the process. Which ever document is created to define the concept of the proposed satellite (or satellites) should specify these and any other known mitigation techniques applicable to the target orbit. At this point, mitigation measures and practices should be addressed in the System Operations Concept. The emphasis during this phase is to increase the awareness of debris; its potential impact on operations and ways to mitigate the attendant risk.

The requirements definition phase needs to produce clear mitigation requirements for each segment of the program: satellite, launch vehicle, operations. Making the debris knowledgeable engineer the "Cognizant" or "Responsible" engineer for the debris mitigation requirements is a very good way to help disseminate, then advocate and defend those requirements. The satellite needs to have requirements for minimizing "operational" debris associated with deployment, stabilization, and orbit raising (and lowering as appropriate). The launch vehicle should have similar (if not identical) requirements as well as venting requirements. Operations needs to have requirements to conduct system operations such that the explosion and collision hazard is minimized. An example from the Iridium® program follows.

Nickel hydrogen batteries have become more and more common in satellites. Engineers need to become familiar with the design features to minimize the likelihood of their exploding. We asked noted Russian battery expert Boris Tsenter to provide his expertise to our design process. He explained why a Russian satellite with NH_2 batteries had exploded and how to design a battery to virtually eliminate re-occurrence. In addition to design feature he pointed out operational procedures necessary for reducing the explosion potential. Specifically, he recommended that the battery never be left "open". Thus, operations has included in their procedures the requirements to leave the battery in charge or discharge (at least trickle). As the keepers of on board software operations must also ensure these requirements are embedded in the correct location in the on board software, especially any "safe mode" software.

The next phase is perhaps the most critical: the design phase and its accompanying trade off analyses. As the program matures and grows, the awareness of the importance of debris mitigation may diminish due to the sheer numbers of engineers on the program. The debris mitigation knowledgeable engineer or subcontractor needs to be a part of every design review or technical interchange meeting to advocate and defend mitigation requirements. Compromises inevitably must occur but, desirably the process allows informed decisions on the various trade-offs.

The final phase of a program is system operations. Hopefully, requirements will have been implemented and operators will have been schooled in mitigation measures. Procedures will have been developed and validated. Policy rules of engagement from management should be in place so that these procedures, whether manual or automated, are executed in a timely manner under the defined constraints.

Thus far, the only cost to a program for mitigation has been the cost of the engineer(s) or subcontractor. Depending on the size of the program, a full time debris mitigation engineer may not be justifiable. The best solution is to find a debris mitigation knowledgeable "system engineer" who can perform other engineering tasks as well. An Astrodynamicist also works well since every program needs an "orbits" person. This person can facilitate increased awareness of debris mitigation and indoctrinate other engineers. He or she can recommend courses, seminars, conferences, or reading material to increase the number of debris mitigation knowledge people on the staff.

In the ideal situation, when a program has followed the path just described, costs to a program should be virtually zero...especially when the debris mitigation knowledgeable person(s) is a qualified system (or other discipline) engineer whom the program needed anyway. Since the program had to design a system to perform a function, the delta cost for requiring that same system to include debris mitigation features will be very small. For example, the reliability of the on-board computer(s) will most often be high enough so that mitigation measures (safe mode and de-orbit in particular) do not drive the requirement. The mission requirements for 3-axis stability also almost certainly are more demanding that de-orbit stability requirements. About the only areas where one might be able to identify costs for mitigation is fuel. De orbit requirements may drive the size of the tank to store the fuel and obviously the fuel itself must be in the mass budget for the satellite. I assert, however, that early specification of the associated requirements will result in near zero cost delta: simply place the de-orbit fuel in the budget in the beginning and design around it. As to the mass, most launch providers charge by the launch so the mass associated with de-orbit fuel is indistinguishable from all the other mass being launched. So the only identifiable cost, in the ideal, is the cost of de-orbit fuel: a few bucks a gallon for hydrazine.

3. Conclusion

The key technique in debris protection and mitigation is to obtain a debris mitigation knowledge engineer early in the life of the program who is qualified in other disciplines: someone the program would have hired anyway. Declare this person to be a "Cognizant" or "Responsible" engineer in program documentation. Involve the person through Concept and Requirements Definition phases and into the Design phase. Use this person to generate the necessary documentation to be used in training the operations folks and in the execution of mitigation policy.

But this engineer won't get hired and no one will listen unless the top management of the program commits to debris mitigation. Only with management support will this person get hired and then be able to convert the masses of program personnel to enable building and operating a satellite system that doesn't worsen the debris problem. Hopefully, this paper will convince top management of future programs that debris mitigation can easily be done very cost effectively and thus motivate them to hire and support the efforts of debris mitigation knowledgeable engineers.