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FUTURE TECHNOLOGIES FOR SATELLITE OPERATIONS CENTERS

Dr. Scott R. Turner
Dr. Kenneth D. Shere
The Aerospace Corporation
Dr. Edward G. Howard
NOAA/NESDIS

Introduction

The National Environmental Satellite, Data, and Information Service office (NESDIS) of NOAA asked the Aerospace Corporation to survey current and emerging ground system technologies and identify technologies that were likely to have a substantial impact on satellite operations in the 5-10 year timeframe. From the study, we identified sixteen key ground technologies and six key space technologies.

Methodology

Anyone who keeps abreast of technology news knows that new technologies are constantly being invented. This study faced a two-fold challenge: First, to identify the technologies that were likely to transition from the chalkboard or breadboard stage to commercially viability, and second, to further narrow those technologies to the ones that would be relevant to NOAA's future ground operations.

To meet this challenge, we devised a two-part process. The first part was a top-down approach that used *scenario-based planning* to determine what technologies would be relevant in NOAA's future ground systems. The second part was a bottom-up *technology survey* that analyzed current and emerging technologies for commercial viability. The two approaches were then intersected to identify the technologies that were both relevant and likely.

In this paper we describe the scenario-based planning process we used to determine technology relevance. (We will detail the technology survey we used to determine commercial viability in a paper for the 2004 Satellite Operations Conference, May 17-21, 2004 in Montreal Canada.)

Scenario-Based Planning

Planning for the future is difficult because the future is notoriously unpredictable. At any moment there are many possible futures; plan for any one of them and you'll surely be wrong in many ways. Scenario-based planning addresses this problem by planning not for one future but for several futures.

In this study, we used the Proteus[1] methodology. In this approach, we try to cover all possible futures by identifying several representative but divergent futures. We then analyze this set of future scenarios for commonalities. Anything that appears in all the divergent future scenarios is very likely to occur in the real future.

The Proteus methodology uses a five-step process to envision likely but divergent futures. This process is shown graphically in Figure 1.

* Dr. Scott R. Turner, The Aerospace Corporation, 15049 Conference Center Dr., Chantilly, VA 20151; email: srt@aero.org

Identify Possible Drivers	Group Drivers into Dimensions and Select Values across Future	Alternative Future Worlds (Scenarios)	Impacts on NOAA for each Scenario	Common Technologies Across Scenarios

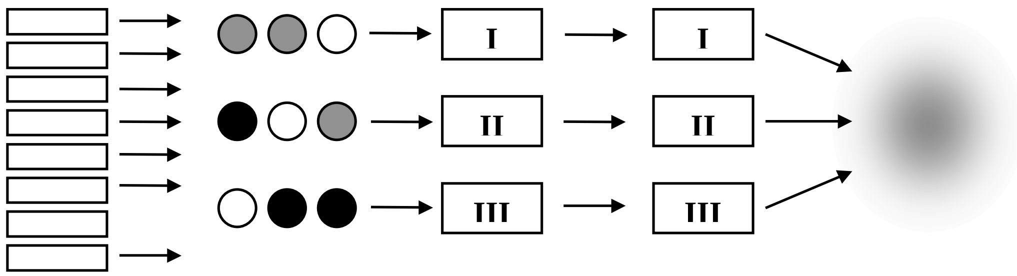

Figure 1 Proteus Methodology

The process begins by identifying *drivers.* Drivers are business and societal trends that could impact NOAA's future. For example, "Commercial demand for earth-sensing data" and "Global stability" are both potential drivers for NOAA.

In this study, we identified 43 drivers. It is cumbersome to work with so many drivers, so the second step is to group similar drivers together into "dimensions". We reduced the 43 drivers to four broad dimensions: (1) Availability of oceanographic, atmospheric and land products,(2) Level of access to resources in pursuit of health and happiness,(3) The level of political, environmental regulation, and (4) The degree to which people are free from threats to health and safety.

The third step is to assign values to these dimensions to create future scenarios. Scaled values (e.g., "high" vs. "low") are suitable for some dimensions, but in general we draw from the underlying drivers to be more specific when instantiating a dimension. As an example, the value for the "Security" dimension in one of our scenarios is "Food shortages outside of US, global instability, and increased terrorism (primarily abroad)."

We then group these values to create divergent future scenarios. Ideally we create scenarios that don't share the same value in any dimension. In this study, we created five scenarios shown in Table 1.

Once a set of representative and divergent future scenarios has been created, the next step is to analyze each scenario for the impact it would have on NOAA, and the technologies it would require. For example, one impact of the "Bunker Mentality" scenario would be governmental direction to NOAA to share data and facilities with Department of Defense partners. To work closely with the Department of Defense would require NOAA to implement strong computer security; so "computer security" is a technology needed in the "Bunker Mentality" scenario.

Scenarios	Availability of oceanographic, atmospheric and land products	Level of access to resources in pursuit of health and happiness	The level of political, environmental regulation.	The degree to which people are free from threats to health and safety
Bunker Mentality	Limited availability of data to govt. approved customers	Long-term economic depression	Micromanaged	Terrorist threats, active wars with US involvement, extreme concern
Utopia	On-demand to everyone at no cost from the govt.	Long lifespan, wealthy populace with high access to cheap resources	Regulated for the common good	No significant threats
Food Fight	On-demand to some from govt., commercial data available internationally	Limited energy resources in the US, fresh water shortages in the US, good access to other resources	Regulated	Food shortages outside of US, global instability, increased terrorism (primarily abroad)
Urban Headache	Available on demand from govt., fee-for-service	Limited transportation resources, urban congestion, mega-cities	Shift of power from federal to local governments, high level of local regulation	Significant domestic terrorist threats (primarily in urban areas), no threats of war
Commercial Space	On-demand from commercial providers	Some part of the populace has limited access to resources	Laissez faire, privatized, few regulations	No significant threats

Table 1 NOAA Scenarios

The final step of the Proteus methodology is to look at the necessary technologies across all the scenarios. Technologies that appear in all (or most) of the scenarios are technologies that are likely to be relevant to NOAA's future, because the technology is required in all the divergent futures.

For example, the "Bunker Mentality" scenario requires strong computer security so that NOAA can interface with the DoD. The "Commercial Space" scenario also requires strong computer security, but for a completely different reason. In this case, strong computer security is needed so that NOAA can sell and buy data from commercial providers. As this illustrates, a technology can be key in different scenarios for different reasons.

As a *sanity check*, NOAA government personnel and Aerospace personnel in our NOAA program office reviewed the impacts on NOAA and the technologies we felt are most likely to impact NOAA ground systems. This coordination also assured us that we did not overlook anything that seems clear to NOAA developers and operators.

Results

After all the scenarios were analyzed for impacts to NOAA, the technologies that appeared in four or more scenarios were extracted and intersected with the results

Ground

- Advanced Display Technologies
- Advanced Memory Technologies
- Advanced Web Technologies
- Autonomic computing
- Biometrics
- Computer Performance
- COTS Ground Systems Software
- Digital rights management
- Distributed trust and authentication mechanisms
- Grid computing
- Hardware security devices
- Intrusion Detection
- Networking
- Quantum Computing
- Software Agents
- XML

Space

- Autonomous Satellites
- Hyperspectral Sensing
- Nanosatellite Technology
- On Board Optical Interconnects
- Space-Based Packet SwitchedCommunications
- Spacecraft crosslinks

Table 2 Identified Technologies

of the technology survey. This resulted in a list of 16 ground technologies and 6 space technologies. These technologies are shown in Table 2. These are technologies that are likely to be commercially viable and relevant to NOAA's ground systems in the next 5-10+ years.

Summary

One of the challenges we faced in identifying future technologies for NOAA's ground stations was determining what technologies would be relevant to NOAA five or ten years in the future. Scenario-based planning provides a reliable method for exploring the future and identifying technologies that will be relevant to an organization.

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[1] M. S. Loescher, C. Schroeder and C. W. Thomas, *Proteus: Insights from 2020*, The Copernicus Institute Press, 2000.