Current and Emerging Ground System Technologies

Dr. E.G. Howard (NOAA, National Satellites and Information Services)

Dr. S.R. Turner (The Aerospace Corporation, Engineering Technology Group)

Dr. K.D. Shere (The Aerospace Corporation, Civil and Commercial Operations)

Executive Summary

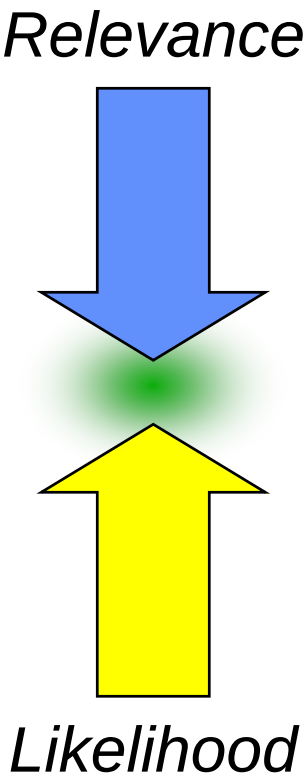
- **Purpose**
  - Survey current and emerging ground system technologies and identify technologies that are likely to have a substantial impact on satellite operations
- **Methodology**
  - Bottom-up technology assessment combined with
  - Top-down impact assessment
- **Results**
  - Identified 22 high-impact emerging technologies
  - Provided detailed analysis of technologies

Agenda

- Executive Summary
- **Process Description**
  - Scenario Based Planning
  - Technology Assessment
- Results
- Conclusions

Process Description

- **Top-down:***
  - Scenario Based Planning methodology
  - Predict the future (business & societal trends)
  - Analyze the future for *relevant* technologies
- **Bottom-up:**
  - Ask top technologists to predict *likely* future technologies
  - "Engineering Approach"
- **Merge the two approaches to find the common ground.**
  - ***Relevant, likely technologies***



* K. Shere and S. Turner, American Meteorological Society, Proceedings of the Annual Meeting, December 2003

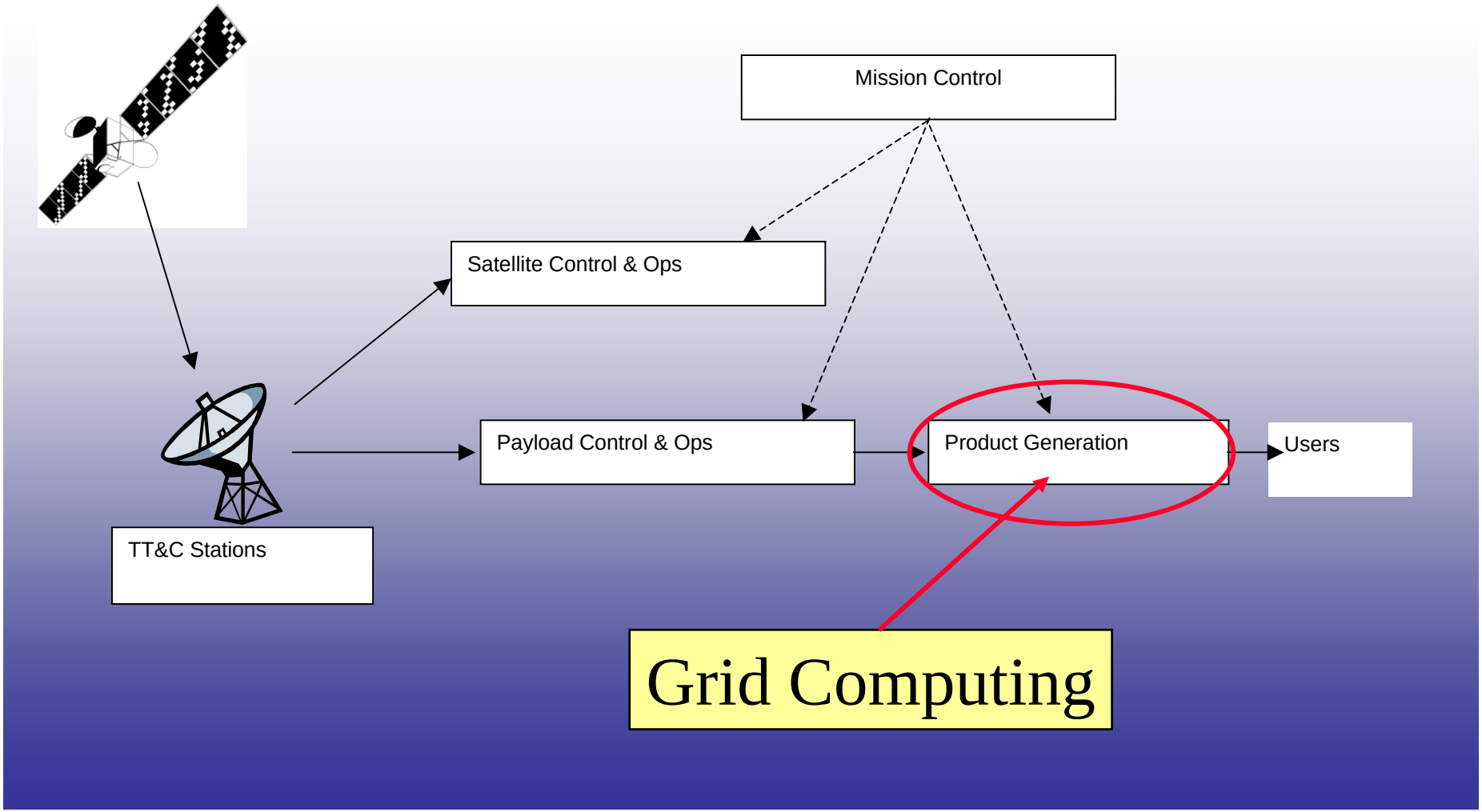
Engineering Approach

- **Technologists identify current and emerging technology trends**
  - Internal Sources
    - Aerospace Information Technology Forecast (ITF) – database of over 400 technologies
    - Aerospace research reports
    - Aerospace and NOAA experts
  - External research publications, conferences, surveys
- **Evaluate maturity**
  - Based on NASA's Technology Readiness Levels (TRLs)
- **Identify area of impact upon ground stations**
  - By functional mission areas
  - By generic ground system architecture

Technology Readiness Levels

TRL	Description
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof-of-concept
4	Component/subsystem validation in laboratory environment
5	System/subsystem/component validation in relevant environment
6	System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space)
7	System prototyping demonstration in an operational environment
8	Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space)
9	Actual system "mission proven" through successful mission operations

Impact Assessment



Format of a Technology Assessment

	Description	TRL	Hyperlinks	Impact Areas: Functional: Routine Operations	Anomaly Resolution	Information Archival	Mission Data	Ground Rcv &	Architectural: Launch & Earlv Orbit	End of life	TT&C Stations	Data Distribution	Satellite Cntrl & Ops	Payload Cntrl & Ops	Mission Control	Product Generation
Grid computing	**Massively parallel computing in which all of the PCs and other computers in a company or organization are connected by (high speed) networks, and applications are run in a way that utilizes cycle time available on a large number of the machines.**	9	*Software Practice and Experience*, Oct. 2002 http://www.gridtoday.com/index.html	1	4	1	3	3	3	1	1	3	1	1	2	5

Major Impact Areas

Results of Engineering Assessment

- **Multi-page spreadsheet containing both ground and space technologies.**
- **68 technologies**

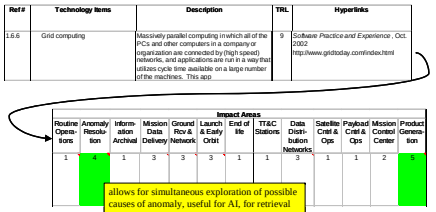
Putting It All Together

- **Developed a technology list**
- **Developed scenarios**
- **Each technology evaluated against the following criteria:**
  - Importance to the scenarios
  - Potential near-term impact to operations
- **Two-page descriptions were developed for each technology satisfying *either* criterion**

Top Down Scenario

	Availability of Data Products	Wealth level	Regulation level	Threat level
Bunker Mentality	Limited availability 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 and fresh water in the US, good access to other resources	Regulated	Food shortages outside of US, global instability, increased terrorism
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	Limited access to resources	Laissez faire, privatized, few regulations	No significant threats

Bottom Up Engineering



Ref #	Technology Items	Description	TRL	Hyperlinks
I.6.6	Grid computing	Massively parallel computing in which all of the PCs and other computers in a company or organization are connected by (high speed) networks, and applications are run in a way that utilizes cycle time available on a large number of the machines. This app	9	*Software Practice and Experience* , Oct. 2002 http://www.gridtoday.com/index.html

Impact Areas												
Routine Operations	Anomaly Resolution	Information Archival	Mission Data Delivery	Ground Rcv & Network	Launch & Early Orbit	End of life	TT&C Stations	Data Distribution Networks	Satellite Cntrl & Ops	Payload Cntrl & Ops	Mission Control Center	Product Generation
1	4	1	3	3	3	1	1	3	1	1	2	5

allows for simultaneous exploration of possible causes of anomaly, useful for AI, for retrieval of information from documentation that is widely distributed

Operational Input

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Survey of Current and Emerging Ground System Technologies:
Final Report

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Prepared by

Dr. Kenneth Shere
Computer and Systems Engineering Subdivision

Dr. Scott Turner
Ground Systems Department, Computer and Systems Engineering Subdivision

Reconnaissance Systems Division
The Aerospace Corporation

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THE AEROSPACE CORPORATION
CHANTILLY, VIRGINIA

Sample Technology Description

Autonomous Operations

- Description
  - We are using the term *autonomous operations* to refer to decision-making activities achieved without the help of ground controllers or operators. Technically, automated decision making could be done on either the ground or in space. Autonomous operations of satellites cover …
- Readiness Level
  - Much of the technology needed for autonomous operations is at readiness level 8 or 9. The technology related to health and welfare is mature; however, operators of earth-orbiting satellites are reluctant to allow autonomous operations. …
- Impact on NOAA
  - Autonomous operations are quite different from the way GOES, POES and DMSP are operated today. Commanding would focus on payload utilization rather than routine operations. The result …
- References
  - http://ic.arc.nasa.gov/ic/projects/Auton-ops/Auto-Ops.group.html
  - http://www.interfacecontrol.com/marketing/pdf/clementi.pdf
  - …

Results Overview

- Identified 16 ground technologies and 6 space technologies

- **Advanced Memory Technologies**
- **Advanced Web Technologies**
- **Computer Performance**
- **COTS Ground Systems Software**
- **Distributed trust and authentication mechanisms**
- **Hardware security devices**
- **Intrusion Detection**
- **Networking**
- **XML**
- **Advanced Display Technologies**
- **Autonomic computing**
- **Biometrics**
- **Digital rights management**
- **Grid computing**
- **Quantum Computing**
- **Software Agents**
- **Autonomy**
- **Hyperspectral Sensing**
- **Nanosatellite technology**
- **On Board Optical Interconnects**
- **Space-Based Packet Switched Communications**
- **Spacecraft crosslinks**

Near-Term Ground Technologies (1 of 2)

- **Advanced Memory Technologies**
  - Improved capacity and reduced costs for primary, secondary and tertiary storage.
  - $1 / terabyte primary memory, $0.10 / terabyte secondary by 2015
- **Computer Performance**
  - Moore's Law (performance doubles every 18 months)
  - 24 GHz desktop by 2015
- **Networking**
  - Robust, high bandwidth, adaptive and wireless networks
  - Needed for expected data rates / volumes
- **COTS Ground Systems Software**
  - Available for Satellite Telemetry, Tracking, Command and Control, Network monitoring and management, and workflow management.
  - "Off the Shelf" SOCC

Near-Term Ground Technologies (2 of 2)

- **Advanced Web Technologies**
  - The semantic web, web data mining, and intelligent search engines
  - Sophisticated presentation and analysis of information using the Web
- **XML**
  - Extensible Markup Language
  - Enable interchange of data within and without NOAA
- **Distributed trust and authentication mechanisms**
  - Data and identity security in complex distributed systems
  - Distributed, virtual organizations
- **Hardware security devices**
  - Transparent, integrated, tamper-proof security
  - Enable new business models, partnerships
- **Intrusion Detection**
  - Detect attacks against NOAA systems
  - Protection in a hostile networked environment

Long-Term Ground Technologies (1 of 2)

- **Advanced Display Technologies**
  - 3-D displays, electronic paper, ubiquitous displays
  - New data analysis tools, “instant” SOCC
- **Digital rights management**
  - Use of hardware and software to enforce a set of policies that control the use of digital content
  - New models for distribution and use of NOAA data.
- **Software Agents**
  - A software component that runs in the background, taking actions to accomplish a specific task
  - Efficient workflow and data usage
- **Biometrics**
  - Operator identification by unique attributes of their behavior or body
  - Improved system security

Long-Term Ground Technologies (2 of 2)

- **Grid computing**
  - Hardware and software infrastructure that clusters and integrates computers, networks, databases and scientific instruments from multiple sources to form a virtual supercomputer
  - NOAA shift from data provider to knowledge provider
- **Quantum Computing**
  - Computing using the probabilistic nature of the waveforms of subatomic particles
  - Linear compute times for exponentially complex algorithms
- **Autonomic computing**
  - Self-managed computing systems
  - Reliable computing; elimination of system administration

Space Technologies

Near Term (1-5 Years)
Autonomy
Hyperspectral Sensing

Long Term (6+ Years)
Nanosatellite technology
On Board Optical Interconnects
Space-Based Packet Switched Communications
Spacecraft crosslinks

Conclusions

- **A two-pronged approach to technology assessment:**
  - Top-down: determine organizational relevance
  - Bottom-up: determine technical maturity
- **Many technical opportunities available for satellite ground systems**
- **NOAA continues to work towards technical excellence in satellite operations**