DEPARTMENT OF THE AIR FORCE
42D AIR BASE WING (AETC)
MAXWELL AIR FORCE BASE ALABAMA

Colonel Barry A. Dickey
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50 LeMay Plaza South
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JUN 30 2016

Mr. John Greenewald
[redacted]

Dear Mr. Greenewald

This is our final reply to your January 2, 2014 Freedom of Information Act (FOIA) request, (number 2014-01670-F) for a copy of SPACECAST 2020, June 1994 Volume II. We processed your request under both the Freedom of Information Act and Privacy Act. There are six pages which are partially releasable; 23 pages which are fully releasable in accordance with the following exemptions:

FOIA Exemption (b) (1) protects from disclosure national security information concerning the national defense or foreign policy, provided that it has been properly classified in accordance with Order 13526.

FOIA Exemption (b) (6) permits the government to withhold all information about individuals in "personnel and medical files and similar files" when the disclosure of such information "would constitute an unwarranted invasion of personal privacy."

If you interpret this as an adverse action, you may appeal it to the Secretary of the Air Force within 60 calendar days from the date of this letter. Include in the appeal your reasons for reconsideration and attach a copy of this letter. Address your letter to:

Secretary of the Air Force
THRU: 42 CS/SCOK (FOIA/PA)
50 LeMay Plaza South
Maxwell AFB AL 36112-6334

There is no charge for processing this request.

BARRY A. DICKEY, Colonel, USAF
Commander, 42d Air Base Wing

Attachment
Documents

~~SECRET/NOFORN/WNINTEL/NOCONTRACT~~

SPACECAST 2020

This document has been redacted for release according to DoD 5400.7-R, *DoD Freedom of Information Act*, and Executive Order 13526, *Classified National Security Information*, Section 1.4, para (a), as indicated by "REDACTED" inside blue/gray boxes.

Volume II

Prepared by the Students and Faculty of

AIR UNIVERSITY

Air University
Air Education and Training Command
United States Air Force
Maxwell Air Force Base, Alabama 36112-6428

June 1994

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Volume II

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(U) COUNTERFORCE WEATHER CONTROL

(U) Subject and Problem Statement

(U) This paper proposes a counterforce weather control system (with both space and ground based segments) and identifies the prerequisites necessary for such a system to be feasible. Atmospheric scientists have pursued terrestrial weather modification in earnest since the 1940s, but have made little progress because of scientific complexities, legal battles, social concerns, and the intricacies of control at the local, national, and international governmental levels. Developing a space-based weather control system for military applications enormously compounds this already difficult problem. The costs and risks are extremely high. However, the potential benefits to military powers are even higher; subsequently, military powers will periodically be inspired to investigate the feasibility of a weather control system.

(U) This conceptual counterforce weather control system is developed through a three stage predictive analysis technique:

- conceptualize a desired end state (ability to control weather, at will, as a principle of war),
- hypothesize the preconditions to achieve that end state, and
- develop measures of effectiveness which indicate progress toward that end state.

(U) The desired end state is limited only by imagination. For example, envision the capability to accomplish the following objectives:

- "bore a hole" through a cloud to allow unrestricted surveillance of an enemy target (figure 1),
- create an atmospheric event over an enemy airfield so as to ground all their aircraft (i.e., thick fog or severe thunderstorm), and
- create a weather pattern that obscures your military movement from the enemy.

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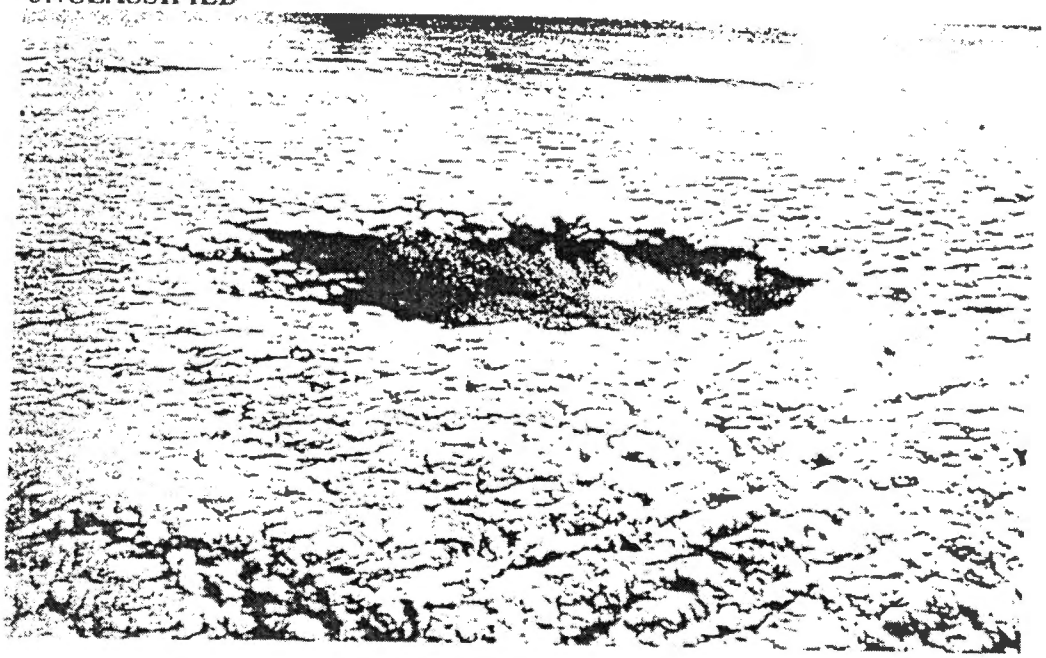

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(U) Figure 1. Hole in cloud deck caused by cloud seeding with silver iodide.

However, the desired end state is limited by scientific capability ("How can I vaporize that cloud?" or "Is it possible to create a city-sized area of fog over that enemy airfield?"), social concerns ("What is the environmental and ecological impact or result of the proposed weather modification?"), and legal/governmental hurdles ("What laws preclude or restrict our proposed weather modification activities?"). These limitations are not impossible to overcome. In fact, it now is scientifically possible to safely vaporize warm clouds with laser radiation (something we could not effectively accomplish a decade ago). However, an operational counterforce weather control system will require a concerted, cooperative effort among scientists, the military, and lawmakers to successfully fund, develop, field, and operate such a capability.

(U) The Capability and Its Relevance

(U) Requirement

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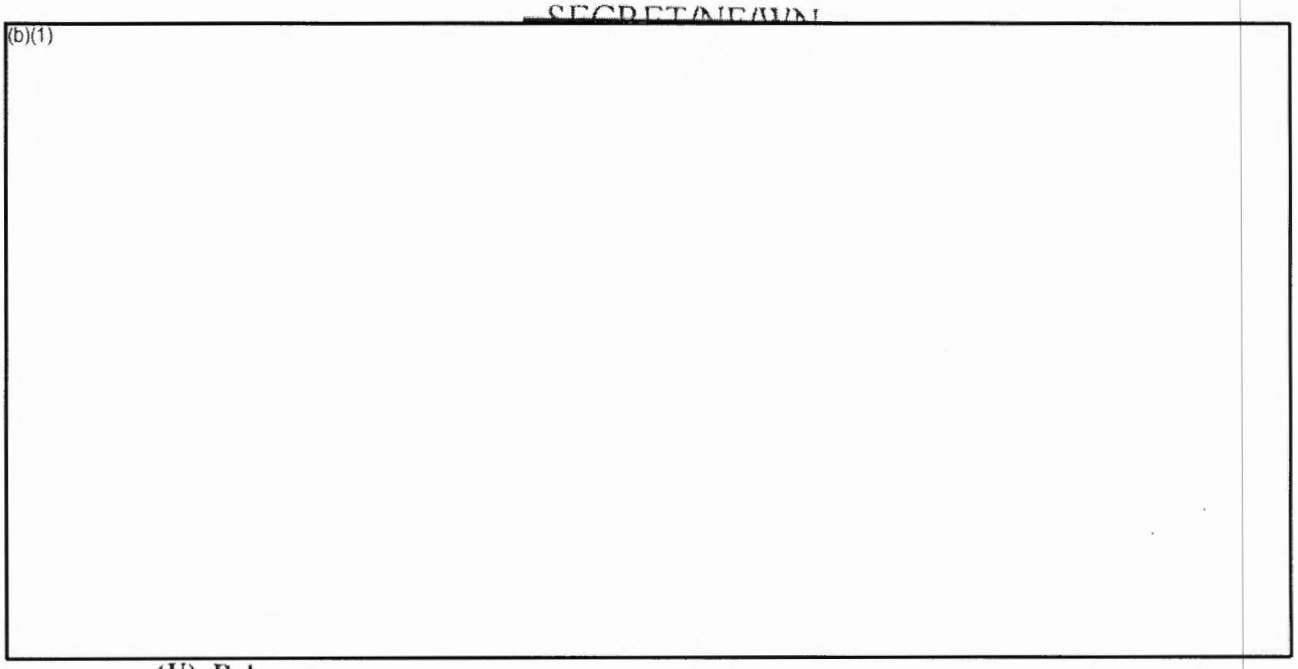

(U) Relevance

(U) The diverse possibilities for the employment of a counterforce weather control system could introduce greater changes in warfare than those which occurred with the first use of nuclear weapons. Severe weather very often inflicts greater damage to military forces than an enemy does. For example, consider the devastation to Homestead AFB FL from Hurricane Andrew (1992)[3], to McConnell AFB KS from the Andover tornado (1991)[4], and to Charleston AFB SC from Hurricane Hugo (1989)[5]. The ability to change the direction of destructive storms away from friendly forces and towards enemy forces would add tremendous capability to a military arsenal. Consider the utility of the following environmental modifications to support military operations:

- dissipate fog or clouds so as to image enemy aircraft capabilities,
- create solid, low overcasts to conceal troop concentrations and movements,
- create extensive flooding in strategic areas,
- artificially induce ionospheric storms to black-out HF communications,
- create/dissipate temperature/humidity to modify refractive indices enough to influence radar or radio transmission, and
- produce precipitation to interfere with vehicle operations.

The US has previously conducted weather modification operations during conflict. From 1966-1972, a joint service rain-increasing program was conducted to impede North Vietnamese infiltration through the Laotian panhandle by further reducing trafficability

during the rainy season. Unfortunately, operational effectiveness of the weather modification efforts was not conclusively demonstrated.[6] However, military interest and programs in weather modification have continued (see "Previous USSR Weather Modification Efforts") and will no doubt continue as the required technologies evolve.[7]

(U) Feasibility

(U) There are several points of view (or camps) regarding hostile use of weather control. They are summarized as follows:

- Pessimists: "Weather control weapons do not hold sufficient promise to warrant expenditure of developmental time or effort,"
- Eventualists: "Weather control weapons will have an important role in military arsenals, eventually;" and
- Moralists: "Weather control weapons, like biological and chemical agents, are too insidious to be used morally in war."[8]

Each of these camps has a spectrum of its own. To successfully develop weather control weapons that address the concerns of all camps, one must demonstrate: scientific feasibility of weather modification at the time and space scales desired (requiring continued investment in research, development, operational test and evaluation); an ability to specify accurately the full effects resulting from the proposed modification (again, requiring the same continued investment); and the non-lethality of weather control weapons.

(U) Weather modification efforts at the microscale (spatial resolution of tens of kilometers and temporal resolution of approximately one hour) hold the most promise of success. These efforts would most likely have negligible long-lasting effects on weather or climatology over large geographical areas but could have substantial military utility for the battlespace commander. The dangers of pursuing weather modification over large time and space scales are seen in the current furor over global warming and the ozone hole, supposedly caused by inadvertent global weather modification (burning of fossil fuels and the use of chloroflourocarbons).[9]

(U) Current US Weather Modification Capability

(U) In 1958, Dr. Joseph Kaplan, who headed the United States Committee for the International Geophysical Year, asserted, "Control by man of the earth's weather and temperature is within the realm of practicality now."[10] As stated previously, substantial weather modification efforts have been underway for almost 50 years. Those efforts have focused on the following areas:

- precipitation enhancement (through cloud seeding),
- storm system modification to suppress hailstorms, lightning, and hurricanes (including efforts to "re-steer" tropical storms),
- fog dissipation (through cloud seeding of cold fogs and laser irradiation/vaporization of warm fogs),
- large scale circulation modification, and
- climate modification (to include simulation using computer global climate models).

These scientific efforts continue today with renewed enthusiasm because of the universal concern of global warming due to inadvertent climate modification. Prospects for a quick solution to climate modification issues are slim. However, microscale weather modification activities hold tremendous promise for success. Essentially, the smaller the space and time scales involved, the easier the problem is to observe, identify, quantify, simulate, and modify. Therefore, to best reduce scientific risk, a space-based counterforce weather control system should initially be used for microscale weather modification.

(U) Previous USSR Weather Modification Efforts

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This demonstrated an ability to generate infrared-defeating clouds, effectively denying overhead surveillance.[12]

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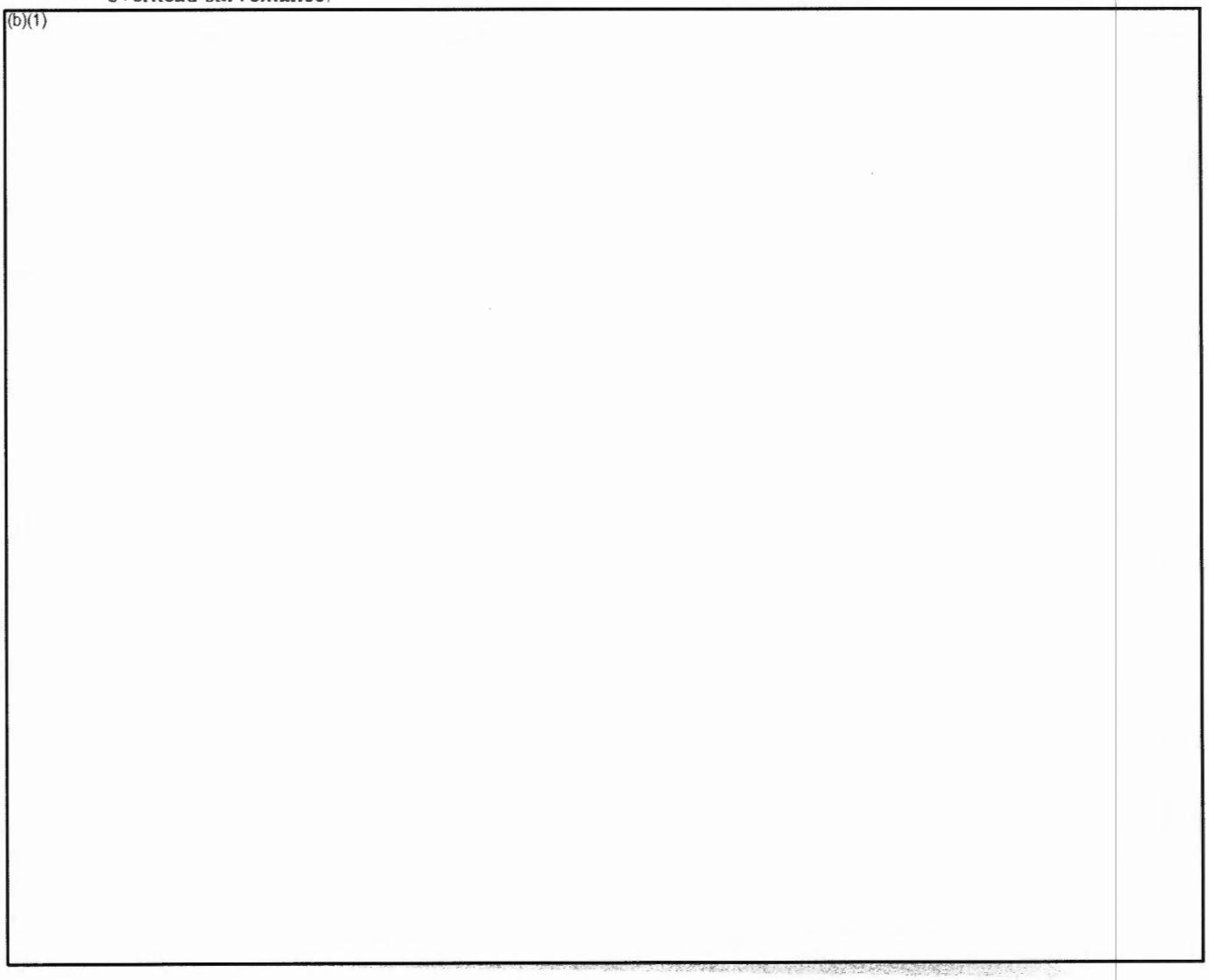

(U) The United States is a signatory of the Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques of 1977 (ENMOD Convention), which prohibits the hostile use of environmental modification techniques having "widespread, long-lasting or severe effects" as a means of damage.[16] The ENMOD Convention gives the following definitions for widespread, long-lasting, and severe:

- Widespread: encompassing an area on the scale of several hundred square kilometers;

- Long-lasting: a period of months, or approximately a season; and
- Severe: involving serious or significant disruption or harm to human life, natural and economic resources or other assets.

Based on these definitions, hostile climate modification would be prohibited, but non-lethal microscale weather modification would not be precluded.

(U) Legal issues are a concern because the technology of weather modification has developed to the stage where many states have found it necessary to enact laws to regulate and control certain weather modification activities (mostly cloud seeding).[17] The legal issues are compounded by the differing attitudes on weather modification between scientists and lawyers, as well as the legal differences among the states (31 as of 1978) that enacted laws dealing with weather modification.[18] Fortunately, the National Conference of Lawyers and Scientists is actively addressing this topic, seeking to better understand the technology, encouraging better research efforts, and promoting more reliable methods of measuring the effects of technological innovation in weather modification.[19]

(U) A Proposed Roadmap for an Initial Counterforce Weather Control System

(U) An initial counterforce weather control system, designed to modify weather over a city-sized area will require the following elements:

(U) A global, on-demand weather observation system. Current weather satellites do not provide this required instantaneous access. Geostationary weather satellites provide data at a time resolution of only 30 minutes and spatial resolutions of 1 km in the visible and 5 km in the infrared. Near instantaneous weather data is certainly possible by 2020. This type of access is required as the first and last step in the system. One must know, instantaneously, what the current weather is in the area of concern before that weather can be modified. Also, after the weather is modified, "visual" access is needed for "weather battle damage assessment (BDA)" so that a decision can be made regarding follow-on modification, if needed.

(U) A weather modeling capability to determine the effects of modification. Ideally, this would require massively parallel computing capability and large communication capability. The idea would be to simulate the proposed modification, evaluate the effects, and, if the effects are satisfactory, initiate the proposed modification.

(U) A space-based, directed energy weather "modifier." Although the modification could certainly be ground-based, space-based modification gives the commander near instantaneous capability to modify the weather. The reaction time from ground-based systems would be too long. Potential modifier technologies are discussed below

(U) A command center with the necessary communication capabilities to observe, detect, and act on weather modification requirements

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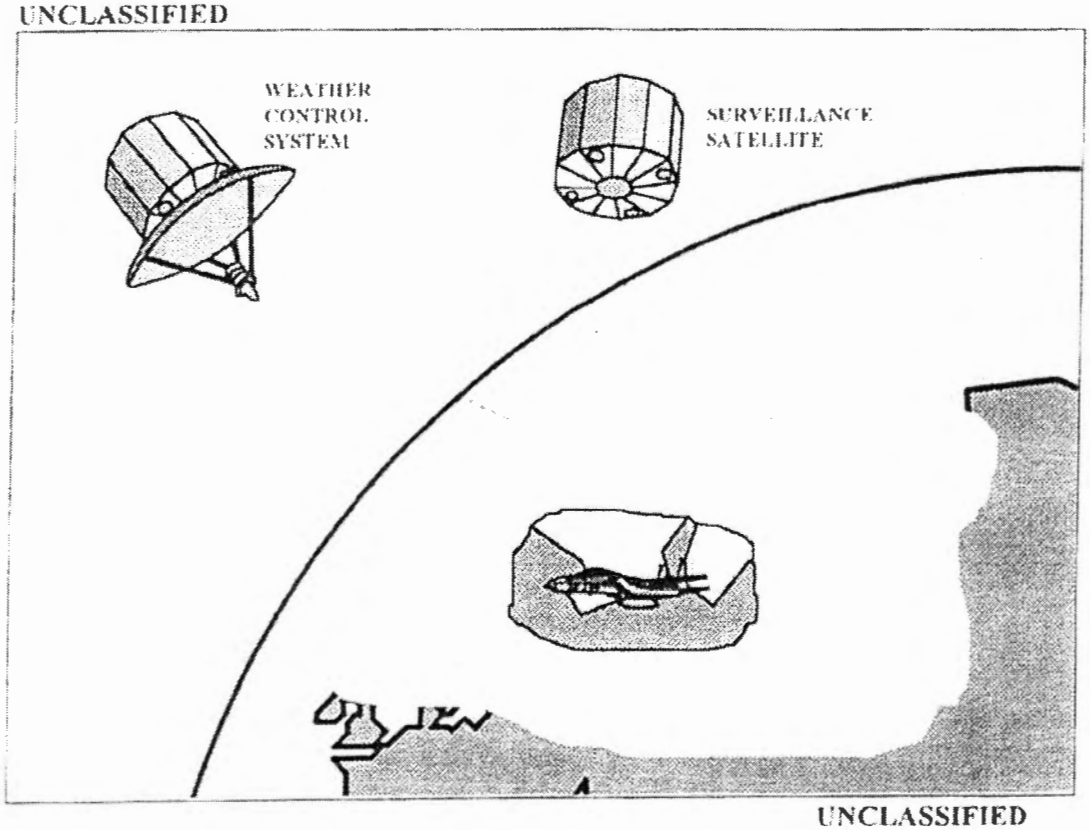

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(U) Figure 2. A prospective counterforce weather control system, which bores a hole in a cloud deck to allow follow-on surveillance of enemy forces.

(U) Potential Technologies

(U) The required technologies necessary to develop and operate a counterforce weather control system fall into four areas: weather satellites that continuously and instantaneously monitor the globe, atmospheric modeling; methodologies to physically

modify the environment from space; and energy sources/exploitation to support the modification methodologies.

(U) Weather Satellites

(b)(1)

(U) Atmospheric Modeling

(U) Atmospheric models, both research and operational (used for daily weather forecasts), rely heavily on super computer usage. Currently, there is a concerted international effort to develop global climate models (GCMs) so as to better understand and predict any possible global warming (or cooling) due to inadvertent, anthropogenic changes to the atmosphere. Those GCMs, and any model developed to predict microscale weather events, rely on accurate initialization data, which is largely provided by weather satellites. Earth and atmospheric scientists developing these models are actively supporting the proposed Earth Observing System (EOS). When operational, EOS will provide a basis for developing and/or refining predictive models of the Earth environment for use in specifying and quantifying atmospheric responses to weather modification actions. This system also supports the fundamental requirement for instantaneous, on-demand observation of the Earth's weather. The current dilemma is that EOS has been reengineered and downsized over the past several years because of budget cuts. Additionally, in September, Vice President Gore directed NASA and the Departments of Commerce and Defense to investigate the convergence of EOS, the National Oceanographic and Atmospheric Administration (NOAA) geostationary and polar-orbiting weather satellites, and the Defense Meteorological Satellite Program polar-orbiting satellites into one system for cost savings. The risk, as seen by the scientific community, is that if convergence occurs, science will be sidelined by operational demands of the new converged system.[21] Scientists will continue to place very high priority on the research

objectives of EOS, which are instrumental to achieving the modeling capability that is instrumental to an effective counterforce weather control system.

(U) Furthermore, the National Meteorological Center has proposed an evolutionary restructuring toward National Centers for Environmental Prediction (NCEP). NCEP will include an operational numerical modeling suite and a supporting research and development program. One of their proposed models is a storm-scale model with very high resolution (100-200 meters) covering a limited but moveable domain. The model is being developed now and should be adapted for operational use by early next century.[22] The NCEP long-range plan assumes that super computers capable of hundreds of terraflops will be available early in the next century (as compared to the gigaflops capability of the Cray Y-MP). This future super computer capability is essential to the successful operational capability of a storm-scale model with 100 meter spatial resolution.[23]

(U) Space-based Environmental Modification Methodologies

(U) Numerous methodologies for space-based weather modification have been proposed. First, a system of orbital mirrors (25 to be assembled in space) has been proposed to redirect solar energy to control temperature patterns. The size of each mirror would be 315 square miles so as to irradiate a 225 square mile area from polar orbit. Of course, this system would require substantial spacelift, as well as a construction team (either astronauts or robotics).[24]/[25] A related system has been proposed that uses large arrays of lens, mirrors, and shields to also focus additional solar radiation on a target area.[26]/[27] Second, space-based lasers could be used to irradiate and vaporize fog and clouds.[28] A current capability and its logical space-based follow-on utility is discussed below. Third, one could use space-based microwave energy transmission for both limited area temperature modification and fog/cloud dispersal. For fog dispersal, safety risks would be minimal as most of the energy will be absorbed by the fog droplets. Again, power becomes the critical node.

(U) Energy Sources/Exploitation in Space

(U) As spacecraft increase in size and complexity, larger power systems become necessary. One of the principal areas of emphasis for the source of that satellite power during the past decade has been nuclear power. A nuclear powered system is probably the

only current technology capable of providing the megajoules of energy necessary for space-based weather modification (see section on "Near Term Technologies")

(U) However, the Space Defense Initiative Office (SDIO) sponsored research in space-based nuclear power has diminished substantially. The SP-100 reactor program has been canceled; other efforts to develop space nuclear power sources have "crested and then fallen."[29] Other SDIO power/propulsion work demonstrated the feasibility of generating nuclear power in space and beaming it back to earth.[30] Reversing the order (generating nuclear power on earth and beaming it to a satellite) would be technically feasible, but would add additional system complexity that would not be preferred.

(U) Near Term Technologies and Operational Exploitation Opportunities

(U) Currently, there are numerous ground-based weather modification efforts that hold substantial promise for space-based application. In particular, one team of atmospheric scientists has successfully demonstrated the capability to dissipate warm fog at an airfield with laser irradiation.[31] This 10.6 micron system was tested *in situ* at an airfield with zero visibility. Generating 1 watt/square centimeter, the system raised visibility to one quarter of a mile in 20 seconds. Team members indicated that, in theory, a similar system would be feasible from space, depending primarily on required power.[32] Allowing for a 20 percent system efficiency, one would need a power generation capability of 80 megajoules. This is certainly feasible using the nuclear power systems discussed above.

(U) There are numerous civil/commercial applications of weather modification technologies:

- drought relief through precipitation enhancement,
- flood prevention by storm mitigation,
- energy production, and
- fog dissipation to keep airlines on schedule.

(U) Necessary Technologies

(U) The military significance of weather control has been evident to scientists and lawmakers, as well as military leaders. Dr. Edward Teller, in testimony before the Senate Military Preparedness Committee, stated that the US could become a second class power without war, if another power succeeded in controlling weather to produce rain over their territory and deprive America of needed rain.[33] During a 1966 Congressional hearing on weather modification, Senator Howard Cannon of Nevada stated that "successful weather modification could be an important detail in our national defense posture."[34] Despite the scientific, social, and legal complexities associated with space-based counterforce weather control, the capability to modify the weather from space is certainly possible and feasible by 2020. However, one must pursue an on-demand weather observation system (technically possible today but not currently programmed), the requisite weather effects modeling capability (requiring massively parallel computer capability and further modeling development dependent on the EOS), the demonstration of space-based weather modification by laser, microwave, or harnessed energy (in the early phases of feasibility and dependent on an adequate power source), the necessary spacelift to deliver the system components, and substantial communication capability to integrate and command the system.

Notes

[1] VAdm William F. Raborn, "New Horizons of Naval Research and Development," *US Naval Institute Proceedings*, no. 1 (January 1963): 40-47.

[2] Headquarters United States Air Force, "A Study of Future Air Force Space Policy and Objectives" (U), July 1977, (SECRET/NOFORN)

[3] Hurricane Andrew was the costliest natural disaster in *US* history; preliminary *US* damage estimates were $20-25 billion. Andrew made landfall due east of Homestead AFB with estimated sustained winds of 145 mph and gusts of 175 mph, completely demolishing most base structures. See Max Mayfield and Lixion Avila, "Atlantic Hurricanes," *Weatherwise* 46, no. 1 (February/March 1993): 18-22.

[4] On 26 April 1992, a violent tornado moved across McConnell AFB, destroying homes, an elementary school, and much of the base exchange and commissary. The tornado subsequently moved into southern Andover KS, destroying 84 homes, 14 businesses and a mobile home park where 13 people were killed. See Preston W. Leftwich, Larry F. Wilson, and Hugh G. Crowther, "Tornadoes: Record Pace Continues," *Weatherwise* 45, no. 1 (February/March 1992): 26-27.

[5] Hurricane Hugo made landfall near Charleston on 21 September 1989, with estimated surface winds of 140 mph. See Bob Case, "Hurricanes, Strong Storms Out of Africa," *Weatherwise* 43, no. 1 (February 1990): 27-28.

[6] E.M. Frisby, "Weather Modification in Southeast Asia, 1966-1972," *The Journal of Weather Modification* 14, no. 1 (April 1982): 1.

[7] Maj Thomas A. Studer, "Weather Modification in Support of Military Operations," *Air University Review* 23, no. 6 (Spring 1976): 46.

[8] Ibid., 44-45.

[9]Dean Edwin Abrahamson, "Global Warming: The Issue, Impacts, Responses," in *The Challenge of Global Warming*, ed. Dean Edwin Abrahamson (Washington, DC: Island Press, 1989), 3-34.
[10]Joe A. Morris and Capt Howard T. Orville (USN, Ret.), "Stand By for Climate Control," *Saturday Evening Post* 231 (29 November 1958): 20.
[11]Defense Intelligence Agency, *Military Applied Atmospheric Research--FOC* (U), DST-1820E-475-89, 5 July 1989, ix. (SECRET/NOFORN/NOCONTRACT/WINTELL) Information extracted is SECRET/NOFORN/WINTELL.
[12]Ibid., 3-4.
[13]Ibid., 12.
[14]Ibid., 30-31.
[15]Defense Intelligence Agency, *Environmental Warfare--USSR and China* (U), DST-1820S-475-86, 4 August 1986. (SECRET/NOFORN/WINTELL)
[16]Arthur H. Westing, "Environmental Warfare: An Overview," in *Environmental Warfare: A Technical, Legal, and Policy Appraisal*, ed. Arthur H. Westing (London, England: Taylor & Francis, 1984), 3-12.
[17]Emilio Q. Daddario, "Concluding Remarks on Behalf of the American Association for the Advancement of Science," in *Weather Modification: Technology and Law*, ed. Ray Jay Davis and Lewis O. Grant (Boulder, Colorado: Westview Press, 1978), 121.
[18]W. Brown Morton, Jr., "Concluding Remarks on Behalf of the American Bar Association," in *Weather Modification: Technology and Law*, ed. Ray Jay Davis and Lewis O. Grant (Boulder, Colorado: Westview Press, 1978), 124.
[19]Daddario, 122.
[20]Defense Intelligence Agency, *Meteorological, Earth Resources, and Scientific Space Systems--Foreign* (U), DST-1440S-285-93, 11 February 1993. (SECRET/NOFORN/NOCONTRACT/WINTELL) Information extracted is Secret.
[21]Liz Tucci, "Consolidation of Satellite Systems Questioned," *Space News* 5, no. 10 (7-13 March 1994): 3
[22]Ronald D. McPherson, "The National Centers for Environmental Prediction: Operational Climate, Ocean, and Weather Prediction for the 21st Century," *Bulletin of the American Meteorological Society* 75, no. 3 (March 1994): 363-373.
[23]Ibid., 372.
[24]Capt Phillip J. Stack, *Orbital Mirrors to Control Weather*, Squadron Officer School Aerospace Power Study, Air University, Maxwell AFB AL, 15 July 1963.
[25]Maj Rex Kiziah and Maj Donald Jurewicz, Concept Paper C069.
[26]Richard Schwake, Technology Abstract Paper A0079.
[27]Maj Barbara Moock, Concept Paper C059.
[28]MSgt Gary Youngren, Technology Abstract Paper A0367.
[29]Theresa Foley, "*US* Nuclear Space Projects Ebb Again," *Space News* 5, no. 2 (10-16 January 1994): 1.
[30]Allen J. Klein, "Applications of SDI Technology in Space Propulsion," *The Journal of Practical Applications in Space* 3, no. 2 (Winter 1992): 49-62.
[31]Edward M. Tomlinson, Kenneth C. Young, and Duane D. Smith, *Laser Technology Applications for Dissipation of Warm Fog at Airfields*, PL-TR-92-2087 (Hanscom AFB MA: Air Force Material Command, 1992).
[32]Dr. Edward M. Tomlinson, North American Weather Consultants, Salt Lake City UT and Dr. Duane D. Smith, Kaman Aerospace Corp., Tucson AZ, telephone interviews with author, 12-13 April 1994.
[33]Daniel S. Halacy, Jr., *The Weather Changers* (New York: Harper & Row, 1968), 157.
[34]Ibid., 159.

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GLOSSARY

ACES. Autocalibrating Extreme Ultraviolet Spectrometers developed by Phillips Laboratory

ADSID. Air-Delivered Seismic Detection

AF. Air Force

AFDIS. AFGWC Dial-In System for weather product support

AFGWC. Air Force Global Weather Center, Offutt AFB NE

AFMC. Air Force Materiel Command

AFSPC. New acronym for Air Force Space Command

Amor asteroid. Asteroid having perihelion distance between 1.017 and 1.3 astronomical units (AU).

aperture. The diameter of the primary lens or mirror of a telescope; hence, the best single measure of the light-gathering power of a telescope.

aphelion. The point in elliptical orbit of a planet, asteroid, or comet that is farthest from the Sun.

Apollo asteroid. Asteroid having orbital parameters similar to the Earth's.

ARPA. Advanced Research Projects Agency

Artificial intelligence. A generic term commonly used to indicate the inclusion in software of some type of automated application of rules, the results of which give the appearance of "intelligence" on the part of the computer. An example would be a computer which uses language rules to carry on a conversation with the human using the computer.

ASAT. Anti-Satellite

ASCM. Advanced Spaceborne Computer Module

asteroid. An object orbiting the Sun that is smaller than a major planet (tens of meters to about 1,000 km diameter), but shows no evidence of an atmosphere or other types of activity associated with comets. Most asteroids are located in a belt between Mars and Jupiter from 2.2 to 3.3 AU from the Sun.

astronomical unit (AU). Average distance between the Earth and Sun, equal to about 150 million kilometers.

Aten asteroid. Asteroid having semimajor axis less than 1.0 AU and aphelion distance greater than 0.983 AU.

ATLAS. Aerospace Traffic Location and Sensing

ATN. NOAA's Advanced TIROS-N satellite

ATSSB. Advanced Technology Standard Satellite Bus

Automated assistants. Any of several software tools which can be programmed to automatically find and/or process information according to rules or guidelines given by a specific user of the resultant information. For example, tell an automated assistant to check all the news service articles for the last two months, and report tomorrow at 0800 with all articles which mentioned both Bosnia and any type of US military forces.

AWACS. Airborne Warning and Control System

AWDS. Automated Weather Distribution System; Air Force weather communications and data processing/analysis system used in base weather support

AWN. Automated Weather Network; Air Force high-speed weather data communications network

BDA. Battle Damage Assessment

BMDO. Ballistic Missile Defense Office

bolide. An asteroid or meteor which explodes in the Earth's atmosphere.

Bulletin board. Used in this paper to indicate the on-line (electronic) bulletin boards, where users of the board post notices using modems or network connections such as Internet. Users also read notices and carry out other bulletin board business, such as multiparty on-line conversations where each party types in comments in an ongoing discussion.

C3BM. Command, Control, and Communications and Battle Management

C4I. Command, Control, Communications, Computers and Intelligence

C6I. Command, Control, Communications, Computers and Beyond

CAD. Computer Aided Design

CAT. Computerized Axial Tomography

CC&D. Concealment, Camouflage and Deception

CCD. Charge-Coupled Device. A solid-state detector used for low-light imaging.

chromosphere. Middle solar atmosphere layer defined to begin at the temperature minimum in the solar atmosphere of 4300 degrees Kelvin, extends approximately 3000 km; region where solar flares are observed.

CICBM. Conventional Intercontinental Ballistic Missile

CINC. Commander in Chief

CINCSAT. Commander in Chief Satellite

comet. A volatile-rich body that develops a transient atmosphere as it orbits the Sun. The orbit is usually highly elliptical or even parabolic (average perihelion distance less than 1 AU; average aphelion distance, roughly 10^4 AU). When a comet comes near the Sun, some of its material vaporizes, forming a large head of tenuous gas, and often a tail formed by the solar wind.

COMSEC. Communications Security

CONUS. Continental United States

Corona. Very hot, tenuous, outer layer of the solar atmosphere, fully ionized, affected by the solar magnetic field, region from which solar wind is emitted

Counterforce operations. those space or trans-atmospheric activities aimed at opposing or defending against threatening force anywhere on the planet or in the region of space. Although counterforce activities are defensive in intent, they do not preclude defense by offensive action. Counterforce activities include the use of information and weather as weapons. They also include defense against non-human threats to the vitality and security of the United States and the people on the planet.

CRAF. Civil Reserve Air Fleet

CSLBM. Conventional Submarine Launched Ballistic Missile

CSOC. Consolidated Space Operations Center

CSTC. Consolidated Space Test Center

D. Fractal Dimension

DEW. Directed Energy Weapons

DFCB. Data Fusion Control Bank

DMSP. Defense Meteorological Satellite Program

DNA. Deoxyribonucleic Acid

DOS. Disk Operating System

DSCS. Defense Satellite Communications System

DSP. Defense Support Program

ECA. Earth-Crossing-Asteroid. An asteroid whose orbit crosses the Earth's orbit or will at some time cross the Earth's orbit as it evolves under the influence of perturbations from Jupiter and the other planets.

eccentricity. The measure of the degree to which an ellipse is not circular; ratio of the distance between the foci to the major axis.

ECM. Electronic Countermeasures

Electronic performance support system. A general grouping of software tools to aid productivity. A typical group might include an electronic phone book/rolodex, electronic scheduler/calendar, electronic calculator, project management tool, tutorial(s) on one or more aspects of the job or software, and a database of key information. The objective is to provide the individual with access to the information and tools needed to do the job.

ELINT. Electronic Intelligence

EMI. Electromagnetic Interference

EMP. Electromagnetic Pulse

EO. Electro-optical

EOS. NASA's future Earth Observing System

EUV. Extreme ultraviolet radiation

Expert system. Typically a set of rules or a decision tree which aids an individual to make good decisions in an area where that individual is not an expert. Usually, subject matter experts are interviewed by the software developers to determine the steps the expert would use to make a particular decision. Sometimes experts are followed by note-taking observers as the experts go about formulating decisions. This often reveals that the expert was not aware of all the steps and questions used.

FALCON. Fission Activated Laser Concepts

FLOPS. Floating Point Operations per Second

FNOC. Navy's Fleet Numerical Oceanographic Center, Monterey CA

FPS. Force Protection Satellites

Galactic cosmic radiation. Energetic particles from distant stars and galaxies.

GEO. Geosynchronous Earth Orbit

GEODSSS. Ground-based Electro-Optical Deep Space Surveillance System

GOES. NOAA's Geostationary Operational Environmental Satellite

GPRC. Global Precision Response Capability

GPS. Global Positioning System

GSRT. Global Surveillance Reconnaissance Targeting

GSV. Ground Superiority Vehicles

HF. High Frequency

HUMINT. Human Intelligence

HVA. High Value Asset

HZ. Hertz

IBM. International Business Machines Corporation

ICAO. International Civil Aviation Organization

ICSW. Intercontinental Strike Weapons

IFF. Identification Friend or Foe

inclination. Angle or "tilt" of the object's orbit relative to the ecliptic plane, or Earth's orbit plane.

Information Super Highway. One of the currently popular expressions used to describe the projected network of computer/electronic connections which are to tie education, industry, government, and personal computers together so that information and questions can freely flow between all those connected on any part of the overall network. It has been popularized by and is being pushed by the current vice-president of the US.

INS. Inertial Navigation System

INSAT. India's geostationary weather satellite

interactive. Implying that the user of the software can exert some control over the software, and not just be a passive page-turner recipient. It also usually implies that part of the software design is aimed at adjusting to the needs of each individual user.

Internet. A worldwide computer network that grew out of an originally small network designed by the Department of Defense to allow rapid communication between universities, research laboratories, and military project offices.

IR. Infrared

IRCS. Infrared Cross Section

JEM. Jet Engine Modulation

JSTARS. Joint Surveillance, Targeting and Reconnaissance System

KEP. Kinetic Energy Penetrators

KEW. Kinetic Energy Weapons

kiloton or Kton. Energy equivalent to 1,000 tons of TNT (4.3 and 10^{12} Joules).

KKV. Kinetic Kill Vehicle

Lagrangian points. Points in a two body gravity system of large objects (such as the Sun and Earth) where small objects can orbit the primary body and remain almost stationary relative to the secondary body.

LANDSAT. Earth-sensing satellite managed by NASA

LCS. Laser Cross Section

LEO. Low Earth Orbit

Libration point. Point in between two planetary masses where gravitational forces of the two masses are essentially balanced

LIDAR. Laser Imaging and Ranging Device

LightSat. Light-weight satellite that can be quickly launched.

Logistics activities. Broadly encompassing all the activities aimed at providing and sustaining access to space. These include building and maintaining a space operations infrastructure and training the human resources that sustain space logistics, monitoring and reporting from space, and counterforce operations. In the

SPACECAST 2020 report logistics activities include space research and development, space system design and procurement, space launch operations, on-orbit maintenance and resupply, tracking, telemetry and spacecraft systems commanding (TT&C), de-orbit-operations, and education and training for military space operations.

long-period comets. Comet with a orbital period around the Sun greater than 20 years. Sometimes this class is divided into intermediate period comets (those with orbital periods between 20 and 200 years) and long-period comets.

LPI. Low Probability of Intercept

LWIR. Long Wave Infrared

magnitude. A number, measured on a logarithmic scale, used to indicate the brightness of an object. Two stars differing by 5 magnitudes differ in brightness by a factor of 100. The brighter the star, the lower the numerical value of the magnitude; very bright objects have negative magnitudes. The star Vega (alpha Lyrae) is defined to be magnitude zero.

main-belt asteroids. Asteroids occupying the main asteroid belt between Mars and Jupiter, sometimes limited specifically to the most populous parts of the belt, from 2.2 to 3.3 AU from the Sun.

MARV. Maneuverable Reentry Vehicle

megaton or Mton. Energy equivalent of one million tons of TNT (4.3×10^{16} Joules).

MEO- Medium Earth Orbit

meteor. The light phenomenon produced by an object experiencing frictional heating when entering a planetary atmosphere; also used for the glowing meteor itself. If particularly large, it is described as a fireball.

meteorite. A natural object of extraterrestrial origin that survives passage through the atmosphere.

METEOSAT. Geostationary weather satellite managed by the European Space Agency

MIT. Massachusetts Institute of Technology

Monitoring and reporting Activities. Those directed toward observation and orientation to reduce uncertainties, and to provide communications for the purpose of exercising command of military forces. Although omni-spectral surveillance of the planet and of space are important elements of this area of activity, others include using space and the vertical dimension for the command of forces operating in all media, communications, navigation, and for the information collection and fusion

that, assisted by computational power, results in intelligence. In the area of monitoring and reporting there are many commonalties between national security needs and systems and the systems serving the needs of business and commerce.

MRI. Magnetic Resonance Imaging

MSI. Multispectral Imaging

MSX. Midcourse Space Experiment

multimedia. A term which is commonly used to describe almost any software product which includes multiple types of media, such as color pictures, sound, and video. Multimedia applications are also typically interactive, in that the user can respond to the program and it will in turn adapt to user inputs.

NASA. National Aeronautics and Space Administration

NASP. National Aerospace Plane

NEO. Near-Earth-Object. Objects whose orbits bring them near the Earth. Specifically, Apollo, Amor, and Aten asteroids, and certain comets.

NIH. National Institutes of Health

NMR. Non-Magnetic Resonance

NOAA. National Oceanic and Atmospheric Administration

NODDS. Navy's Naval Oceanographic Data Distribution System

NORAD. North American Aerospace Defense Command

Nowcasting. Forecasting weather, for the next few minutes to a couple of hours using all immediately available weather data

NRL. Naval Research Laboratory

OBC. On-Board Computer

Omni-sensorial. Any of several optical, acoustical, or radio-frequency instruments that using interference phenomena between a reference wave and an experimental wave, or between two parts of an experimental wave to determine wavelengths, wave velocities, distances, and directions.

on-line. Generic term to describe communications or information which is transmitted or available through the use of computer modems or networks. If something resides

on-line, such as an electronic bulletin board, it may have no existence other than the virtual existence in the computer.

opposition. An angle of 180 degrees between a planetary object, the Earth, and the Sun. More simply, these bodies lie on a straight line with Earth in the middle.

OPSEC. Operations Security

OSO. NASA's Orbiting Solar Observatories in the 1960's and early 1970's.

OTHB. Over-the-Horizon Backscatter Radar

perihelion. The place in the orbit of an object revolving around the Sun where it is closest to the Sun.

perturbation. For a body orbiting the Sun or a planet, the gravitational effect of a third body (e.g.,another planet) on its orbit, usually resulting in small changes or periodic fluctuations. [For comets, outgassing near the sun may also act on its orbit.]

PGM. Precision Guided Munition

Photosphere. Lowest part of Sun's atmosphere where sunspots are seen.

PME. Professional Military Education, to include any education or training courses.

POES. Polar Orbiting Environmental Satellite, managed by NOAA.

RBE. Relative Biological Effectiveness

RCS. Radar Cross Section

reconnaissance. A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy.

reengineering. Currently popular corporate term used to describe the act of rethinking and restructuring the processes of a company before overhauling the computer systems within that company. The lesson it seeks to teach is that if you don't go through this rethinking process, the result of the computer overhaul may just be the same mistakes and problems as before, but generated one hundred times faster.

REM. A unit of ionizing radiation in human tissue, equivalent to one roentgen of x-rays.

RF. Radio Frequency

ROE. Rules of engagement

ROSS. Reusable Operating System Software

RULLI. Remote Ultra Low Light Imaging

RV. Reentry Vehicle

S4. Structural Sensory Signature System

SAIC. Science Applications International Corporation

SAR. Search and Rescue

SAS. Situation Assessment Summary

SATKA. Surveillance, Acquisition, Targeting and Attack Assessment

SBV. Space Based Visible Experiment

semimajor axis. Half the major axis of an ellipse. For a planetary orbit, it represents the body's average distance from the Sun.

short-period comet. Comet with an orbital period around the Sun less than 20 years.

SIGINT. Signals Intelligence

SOF. Special Operations Forces

SOI. Space Object Identification

solar wind plasma. Ionized gas consisting of protons, electrons, and other heavy, energetic particles ejected from Sun's corona.

space weather. Variability of the near-Earth and interplanetary space environment.

SPATRACS. Space Traffic Control System

specific impulse. Measure of fuel efficiency.

SSN. Space Surveillance Network

SSTAR. Space Surveillance, Tracking and Autonomous Repositioning

SSTI. Space Surveillance, Tracking and Identification

STEP. Space Test Experiments Platform

surveillance. The systematic observation of aerospace, surface or subsurface areas, places, persons, or things by visual, electronic, photographic or other means.

SWCL. Short Wave Chemical Laser

SWERVE. Sandia Winged Energetic Reentry Vehicle Experiment

TAOS. Technology for Autonomous Operational Survivability

telecommunications. Includes any of the component technologies used for electronic communications over a distance typically greater than that covered by a human shout In the context of this paper it implies two-way communications.

telepresence. Using technology to give the appearance of an individual being present at a location other than the actual location of that individual. An example would be a pilot in a sophisticated simulator which was actually controlling a real airplane 500 miles away, and providing to the pilot visual and other sensory feedback as if the pilot were actually in the cockpit looking out the windscreen and feeling the turbulence. As PME 2020 includes extensive mixing of real and artificial locations and people, many of the references to virtual reality or virtual residency will in context include traditional telepresence as an integral part.

TRIM. Tactical Reentry Impacting Munition

TT&C. Telemetry, Tracking, and Control

UAV. Unmanned Aerial Vehicle

US. United States

USAF. United States Air Force

USSPACECOM. United States Space Command

UV. Ultra Violet

VBL. Vertical Block Line

VESA. Video Electronics Standards Association

VGPO. Velocity Gate Pull Off

VHSIC. Very High Speed Integrated Circuits

virtual environment. An environment which is partially or totally based on computer generated sensory inputs.

virtual learning. The delivery of educational lessons using any of the technologies included in the expanded virtual reality which is the basis for PME 2020's virtual residency.

virtual reality. Immersion of one or more individuals in a virtual environment, with the aim of achieving the illusion that they are in a place, time, or situation different from their actual real-world location and/or time.

virtual residency. In the context of PME 2020, this term means the use of virtual reality, telepresence, and other telecommunication and computer technologies to enable the PME 2020 system to deliver education and training lessons to multiple individuals (usually in geographically-separated locations) simultaneously in a manner giving the appearance and feeling of the individuals being collocated in a traditional seminar. This virtual environment will also allow within it the use of virtual audio-visual tools such as overhead projectors, chalkboards, tape recorders, slide projectors, and multimedia computer programs.

VLWIR. Very Long Wave Infrared

WWII. World War II

WDP. Weapons Delivery Platforms

WMO. World Meteorological Organization, managed by the United Nations