Application of the Complex System Sustainment Management Model to Global Climate Control

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The problem of dealing with Global Climate Change is the problem of controlling a complex system. In the lexicon of Control Theory, the first question is, is the Earth's climate observable and controllable? Beyond that issue is the question of sustainment. That is the main topic of this paper. This second part of the problem is out of the realm of the engineering discipline of Control Theory and falls into the realm of effective and affordable management of a complex system over its lifetime. By comparing the Complex System Sustainment Management Model (CSSMM) to this problem, insights can be attained. The primary insight is the need for a professional sustainment cadre, insulated from passion and politics, to ensure climate scientists and modelers' insights are successfully transformed into useful actions by national leaders. Another important insight is the best way AIAA can help attack this contentious issue in a constructive way without becoming embroiled in the current swirl of unhelpful debate.

I. Introduction

Global Climate Change is a polarizing political topic. There are individuals on both sides of the political debate firmly entrenched in their positions. This paper does not try to influence this political debate, but presents a systems engineering-based methodology for those who desire to mitigate adverse effects. For instance, this approach could tackle the increasing flooding of Venice, shifting of wildlife habitats, or even areas with the most tenuous relationship to climate change, such as inversion-driven poor air quality. Therefore, I urge any reader of any position to continue reading.

Solving Global Climate Change is often characterized by individuals along a spectrum as either pursuing a mirage, an immediate concern, or too late to fix. A more useful approach would be to observe the world around us, determine which changes are adverse that we need to deal with "lead time away", and formulate the plans needed to do so. The systems engineering approach points the way to do this effectively and affordably.

The method described herein was used to keep nuclear-tipped intercontinental ballistic missiles (ICBMs) available and on constant alert despite time-related degradation to the readiness factors of safely, reliability, accuracy, and hardness against attack. This requires "lead time away" thinking since none of these readiness factors can be allowed to degrade in the present.

Based on his career sustaining aerospace systems, primarily ICBMs, the author has written 8 previous AIAA papers on the CSSMM, provided a dozen presentations, almost 100 blog posts, and taught a 2-hour tutorial at the 2019 INCOSE Western States Regional Conference. These products are available at his web site[1] and can be read prior to reading this paper. Alternately, a short description of the CSSMM is provided here for the reader's convenience.

See Figure 1: The Complex System Sustainment Management Model (CSSMM). The model begins with the need for an effective sustainment organization to predict the future of the system they are sustaining. That is, changes to the system required to keep the system useful must be conceived, approved, funded, and completed in time for the system to remain capable of meeting its mission. This "impossible" task is tackled by creating and executing a formal assessment program to observe the emerging failure modes of your precisely defined system.

Fundamental Theorem of Sustainment: *"An effective sustainment organization will always find ways to affordably detect threats to the system in time to correct them before the mission is impacted."*

The goal of this observation of your system is to detect emerging failure modes in time to identify risks and create mitigation plans executed in time to deal with them. This observation and detection is made easier by establishing “readiness factors” associated with the system and its mission. For instance, for ICBMs, the readiness factors are availability, reliability, accuracy, and hardness against nuclear attack. (The additional issues of safe operation and sure employment of nuclear weapons are considered a part of “availability” since failure in these areas will result in the ICBM weapon system being banned or unavailable for use.)

The mitigations get combined into long-range plans that are used to obtain the funds necessary to keep the system sustained. The novice sustainer complains that funding is never adequate for the needs, not understanding that fighting for funding is part of their job description.

By stating the problem of sustainment in this systematic manner, we can use the inputs, outputs, and processes at each stage to establish requirements for the assessment, risk management, and execution programs. The following are examples of requirements derived in this fashion:

- Assessment Program Requirement: Be able to systematically observe the entire system
- Assessment Program Requirement: Update the definition of “entire system” as needed
- Assessment Program Requirement: Be able to systematically observe all mission readiness factors
- Assessment Program Requirement: Update readiness factors as needed
- Risk Management Requirement: Encourage all members to volunteer information
- Risk Management Requirement: Create risk summaries for monthly presentation
- Risk Management Requirement: Hold monthly risk meetings at top and lower organizational levels
- Risk Management Requirement: Obtain and maintain management buy-in and support

For the sake of further illustration, these assessment-related requirements above (and those not listed) lead to a focus on ever deeper understanding of what the system is and what your responsibilities are. For instance, the risk-related requirements lead to the creation of risk integrators as key members of the lower level teams. And this leads to a definition of their duties and their training requirements (as described in my paper, “First Steps” at my web site.).

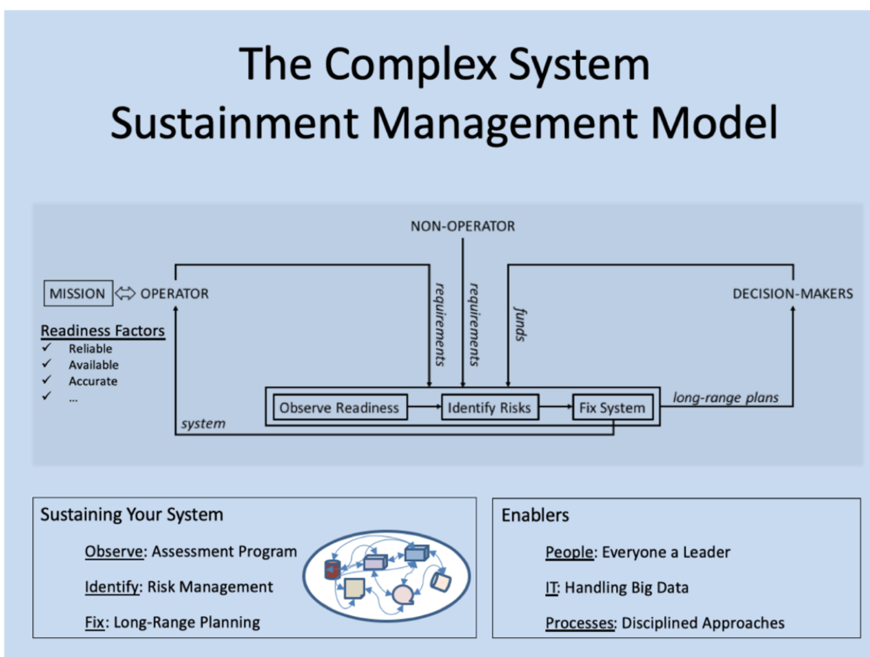

Figure 1: The Complex System Sustainment Management Model (CSSMM)

The execution program drives understanding and further requirements back into the assessment and risk management programs. For instance, in a military example, program element monitors must be able to take risks and long-range plans and succinctly explain them to boards of general officer decision-makers in order to be successful at obtaining funds. This brings more clarity to the authors of the risk listings and program plans as to how these documents can be most useful.

There are 3 “enablers” that are needed to make this approach work. They are “information technology (IT)”, “people”, and “processes”. In brief, the massive amounts of data required to perform observations and make sense of them to the point of creating long-term plans require strict process discipline and a continuing investment in IT resources: data storage, analysis tools, and associated skills that are nimble enough to keep improving these activities. The most important element among the individuals and teams working in these areas is *speaking up*. Processes create continuing opportunities to identify risks, but only individuals can make the choice to speak about them. Individuals who do not speak up (or who demonstrate incompetence in their field) cannot remain on their team.

At this point, the reader should be gaining more insight as to how the CSSMM points both managers and team members towards useful actions on a daily, weekly, and yearly basis. The goal is not to blindly implement the CSSMM but rather to constantly compare sustainment organization activities to the ideal to tease out your priorities.

The most powerful tool available to motivate individuals to contribute is dedication to the mission. In the case of ICBMs, the mission was global nuclear war deterrence. In the case of climate change, unfortunately a consensus on the mission has yet to be reached. For the sake of this paper, the author will make a few initial statements to encourage discussion and refinement in this area:

The mission will likely be associated with survival of the human species in a clean environment over centuries. Readiness factors would be areas such as Anti-Pollution (positive steps taken to keep air and water clean), Species Diversity (to keep ecosystems flexible), Biosphere Energy Management (such as greenhouse gas control to control climate or at least keep the climate in a controllable range), and Global Defense (e.g. asteroid impacts, nuclear war, coral reef collapse, anything that could greatly endanger the biosphere with a single event).

As the biosphere is treated as a massive complex system to be controlled and CSSMM ideas are applied, the first thing that happens is, more clarity is achieved. There is not one “silver bullet” that will reverse all ill effects. There is the need for control and mitigation at many levels.

Controlling and sustaining global climate is difficult for many reasons. One reason not mentioned often in the popular press is, by their nature, ecosystems are constantly changing even when they appear to be stable. For instance, species of plants and animals in a forest can wax and wane over their individual reproduction generations, yet over centuries the forest remains generally unchanged. Understanding the difference between expected variations and clear indicators of climate change is critical in the same way that sustainers must understand the differences between weather and climate, normal and abnormal CO2 cycles, expected and unexpected atmospheric moisture cycles, and many more. While engineers and professional sustainers are comfortable with controlling very dynamic systems, the general public often sees things in a more simplistic way. This sometimes results in so-called solutions that are the equivalent of trying to adjust the car’s speedometer needle in an attempt to slow the car.

Sustainment teams that are expected to control global climate must have the skills to be able to understand these technical challenges. But perhaps the key skill that is generally overlooked is the ability to obtain funding. In the USA, the source of funding is ultimately the average taxpayer, the average voting citizen. Other sources are possible.

By staying focused on these proven approaches to systemic sustainment, managers have a better chance of keeping their teams consistently focused on useful activities instead of spending all their energies reacting to each “crisis of the day” and changing political winds. For instance, enforcing process discipline, hiring useful skills, and purchasing/maintaining needed IT-related tools.

This paper addresses the following:

- Viewing the Global Climate as a complex system
- Determining the observability and controllability of the global climate
- Insights obtained from comparing the CSSMM to the problem of global climate sustainment

But first…

II. The Elephant in the Room

In the United States, at least, the technical issues surrounding global climate change are usually enshrouded in political debate. Perhaps the word *enshrouded* should be replaced by "muddied over" or "obfuscated". That is, the political debate tends to obscure the observations required to identify risks and determine a useful path ahead to mitigate those risks. Political motivations color thinking and individuals with little or no technical or economic expertise drive debates. The decision-makers (in the US, the voters) are influenced to make knee-jerk partisan, rather than deliberative and useful, decisions. Too many politicians are motivated not only by a desire to solve the global climate problems, but also to get re-elected and, for some, to stockpile power.

This leads to extreme and extremely unhelpful pronouncements that serve mostly to satisfy the politician's passionate supporters. One side might have a spokesperson who declares the end of the world in a decade and the other side tells us that it is impossible for puny little man to influence the great global weather system. Both sides carry just enough truth to keep their mission going: stir up people to go out and vote for their candidate.

A grade school education in physics can serve to show (see section IV of this paper) that greenhouse gases can affect air temperatures. And we can directly measure how they tend to build (roughly exponentially) in the atmosphere leading to an explosive model of growth. That math informs us that we are probably *already too late* to fully escape the consequences of greenhouse gas effects even if drastic steps were taken today. Therefore, the "end of the world in a decade" pronouncements are misleading in both negative and positive ways. In a way we are both far too late (to avoid all consequences) and still have time to act (to avoid unmitigated disaster).

The average person attending to their daily tasks do not have the power individually to change global climate even if they achieved drastic changes in their daily lives. Indeed, even the combined efforts of the USA would be overwhelmed by bad actions of India and China as they climb the slope to first world status. Is it even ethical to deny African countries the road to universal electricity? So, there is a ring of truth in saying that no one person will stem the tide. However, this is not a convincing argument to do nothing. It is a good argument to do the right things. Control Systems engineers are familiar with the math required to set up and solve optimization equations. They also know that the math does not pick what to optimize, people do.

To repeat, both extremes are unhelpful. Sadly, this wonky theater also tends to obscure the politicians who are less extreme and have useful ideas for our consideration.

In closing this section, remember that an initial mission statement for this system will need to be created, taken to heart by the team, and modified over time as the sustainers get better at their jobs of understanding the system even as they are sustaining it. What is the mission of global climate? As stated above, a good place to start might be: "Ensure survival of the human species in a clean environment over centuries." But can concepts like "system" and "mission" really be associated with the global climate?

III. Complex Systems

Is it true that a mission is carried out by a system and most all systems have some kind of mission? Is the global climate a system, in the realm of Control Theory and CSSMM?

A system is a set of elements in interaction. It is also defined as a construct of elements that produce results not obtainable by the elements alone. A complex system is a system so complicated that it is not always possible to tell what it will do next[2].

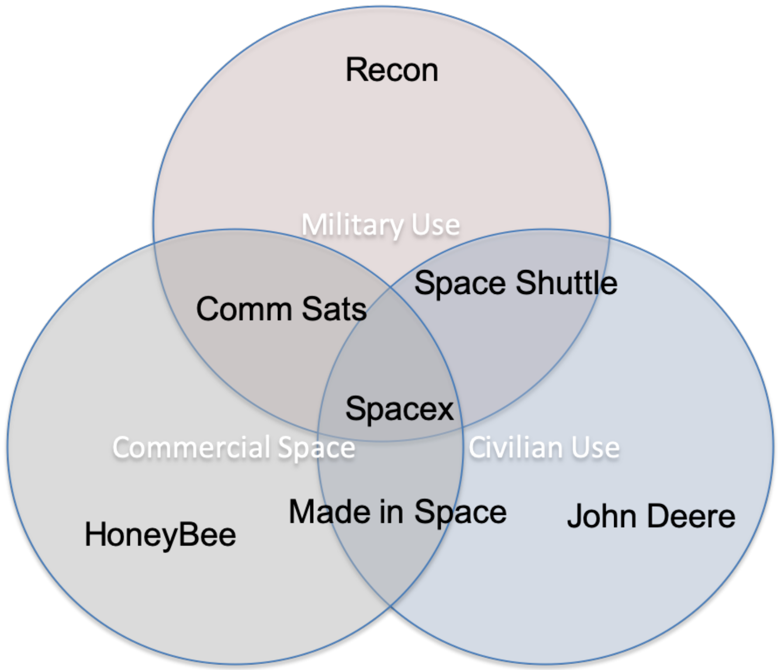

Figure 2: What is a System? Examples of Man-Made Systems

In the vast majority of cases, systems engineers deal with systems that were created by people to achieve specific missions. See Figure 2: What is a System? Examples of Man-Made Systems. John Deere is interested in planting and harvesting. Trane keeps massive buildings or even "systems of buildings" affordably climate controlled. The US Air Force needs to be able to realize its air doctrine of flying over front lines to destroy a nation's industry.

Since the dawn of the First Industrial Revolution when systems started to become ubiquitous and long-lived[3], other phenomena have been noticeable. Sometimes systems arise unpredictably from human activity and achieve unexpected results. The Spanish Flu is credited with killing more people than WWI. There is speculation that its deadliness arose from very specific conditions present in front line trenches[4]. There is agreement that it was no coincidence that its fast and deadly spread coincided with world-wide movement of military personnel. Thus, an unintentional system created by people caused global pandemics that killed millions. In a perverse way, it fulfilled its "mission."

This concept of a perverse mission takes getting used to. But this paper extends the idea of systems even further to those *not* created by people, intentionally or unintentionally. Whether you believe that the Earth's global climate was created by a Supreme Being or arose by some other (perhaps "Blind Watchmaker"?) process, it is apparent by now that it is a construct of elements that produces useful results not obtainable by the elements alone. It is also becoming apparent that it is not always possible to determine what it is going to do next. It is a complex system that fulfills a mission of serving people even if it was not made by people.

Based on this reasoning, the system of global climate is a complex system. So, the next question is, is it a system that is observable and controllable?

IV. Observable, Controllable

The first step in applying Control Theory to a system is to determine whether it is observable and controllable. Discussions about global climate very quickly become incredibly complex, as will be discussed later. This complexity helps muddy discussions of what's happening with it, and what to do about it. In addition, these discussions can become very contentious very quickly. But for the purposes of this section, a few non-controversial facts serve.

See Figure 3: An Easy Experiment to Demonstrate the Greenhouse Gas Effect. It is completely provable by anyone with a heat lamp and a thermometer that James Faraday was correct in his assessment of "greenhouse gases" keeping the Earth a comfortable temperature. Faraday understood that the Earth obtained almost all its heat energy from solar radiation. There is some small contribution from the Earth's core temperature, but this has been shown to be small enough and constant enough to keep the focus on the sun[5].

Objects get warmed by convection, conduction, or radiation. Earth, as a system isolated in space, touches nothing. So, conduction is ruled out. With no atmosphere between Earth and the Sun, convection plays no role. Radiation is the only game in town. But this game turns out to have an interesting twist. Solar radiation after hitting the Earth can and does shift to different bands in the spectrum. In fact, it becomes more intense in the infrared spectrum. When this infrared radiation bounces upwards, some of it impacts water vapor, carbon dioxide, and other gases that absorb and re-emit that energy. This impact and re-emission warms up the biosphere, the part of the Earth we live in and fly our aircraft through.

Thus, if we can show that more greenhouse gases are entering and remaining in our air, and anti-greenhouse gases like sulphur dioxide are not, then warmer air is inevitable. The disagreements arise when we try to establish a simple relationship between gases to temperature. This is not so easy. Also, water vapor comes and goes in a dance we have not fully deciphered yet. Other gases are absorbed and released in their own cycles and their own timing. Air is thinner the higher you go. Air and water currents ebb and flow. And most of these are interacting with each other. In addition, it could be that there are other processes we have not fully discovered yet. Great progress is being made in understanding and modeling all these processes but much remains to be understood.

Underlying all these potentially confusing dynamics is the fundamental mechanism of the proliferating greenhouse gases and their association with what appears to be a (perhaps?) exponential increase in heat energy in our air as greenhouse gases build faster than they cycle out.

Is the Earth's global climate observable? There are numerous examples of circumstantial evidence to confirm the concept of global warming without always being able to tie it directly to the actions of humanity, such as changes in foliage, animal, and insect behaviors. We understand many of the underlying physical mechanisms that likely drive these symptoms. We have various sensors covering the Earth adding to our data each day. We can model many effects and demonstrate a comparison between our models and what we experience over various periods of time. We do not yet have highly accurate, validated models and, the rub is, probably won't before the exponential nature of the phenomena leads to a crisis, at least in the minds of a plurality of Americans.

Verdict: Sufficiently observable, very complex.

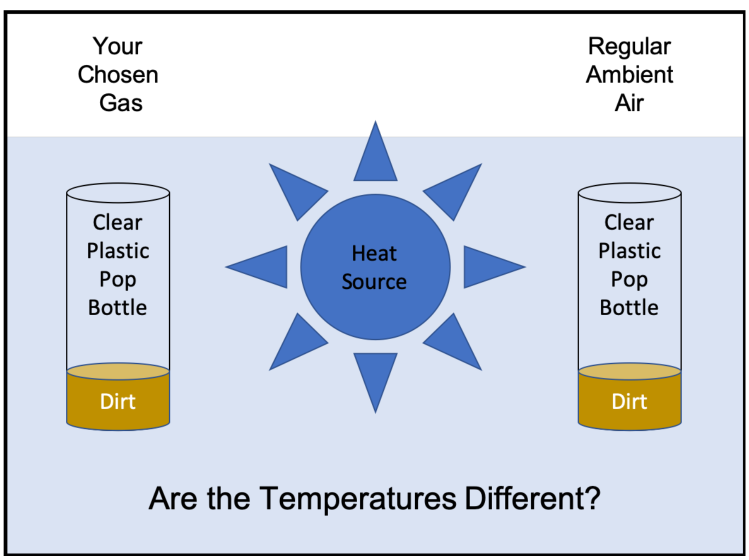

Figure 3: An Easy Experiment to Demonstrate the Greenhouse Gas Effect

Is the Earth's global climate controllable? Yes, in the sense that we have a few clumsy levers that appear to create deterministic reactions. That is, as we continue to burn fuels that release greenhouse gases we do appear to experience somewhat predictable changes in the system at least in direction if not completely correlated in magnitude. To date, options to reverse this action are still limited. We might reduce emissions. We might try to suck certain gases out of the air. We might deploy cover ups like sulphur dioxide (which would create its own problems[6]). As more is learned, more options should emerge. However, there is no guarantee that, under increasing change this system won't enter an unknown state where whatever our current levers are will no longer work[7]. Our system might be chaotic and only controllable within a range that we currently exist in. When that range is exceeded, are all bets off?

Verdict: Controllable enough to encourage further discussion.

V. CSSMM Insights

What insights does the CSSMM provide?

The first step in applying the CSSMM is to have at least an initial working knowledge of what your system entails. In the case of Earth's global climate, the system to be dealt with is actually the Solar System. This is daunting. However, in order to provide a clear understanding of all global climate processes, it will be necessary to study the sun to gauge the consistency of its output, other planets to check this consistency, the voids of space to understand solar storms and Earth's magnetic field, and all of Earth's subsystems and feedback loops.

Daunting as it is, much has already been revealed about these subsystem and feedback loops. Computers and computer models improve each year. There is hope that the system is sufficiently approximated and incrementally improved to call this first step a success. For instance, at this point we can reasonably point to the sun's radiation on the Earth, reflected back into the air, as the primary flux of energy associated with climate change. Thus, most of our focus can be on the solar flux and our biosphere while still encouraging some continued study of the solar system to continue to increase clarity in that area.

Per a previous paper, the next step is implementing a sustainment risk system[8] and associated risk management board. The purpose of this management board is to frequently and periodically take all that is known about the system and its emerging failure modes and state these succinctly in prioritized risk summaries. These are risks to our continued "easy life" on this globe, so some are small and some are big. (Read on to see how this board is limited to ensure they don't become a global governing board.)

For instance, "If the tundra in region ABC continues to warm, then transportation routes in XYZ highway will be unusable." As mentioned earlier, it is likely too late to avoid impacts, so those impacts need to be anticipated and mitigated. Prioritization and mitigations for these risks need to be designed with the understanding of how much lead time is available before impact.

By compiling a list of risks, comparisons can be made among them for the best allocation of resources for mitigations. For instance, which risks are immediate, large, and will take significant time to fix? These scarce resources include the public's limited reservoir of attention. Complaints are legitimate when, for instance, significant focus is placed on recycling plastic bags while we continue to spill massive amounts of unuseful gases into cities from hot water heaters. If the public sees no benefit and considerable downside from a campaign to mitigate a lower risk, we may have lost their support for the bigger risks.

Some risks are very big. "If CO2 continues to be released in the atmosphere at 2018 rates, then global temperatures will increase by y degrees within x years." (This risk statement turned out to be greatly oversimplified as we gained an appreciation for the variability of effects around the globe, thus "global warming" became "global climate change".) And perhaps the mitigations will be big as well. Carbon taxes? Global treaties? Worldwide technology sharing?

Thus, the mitigations will include both stop gap measures to alleviate the impacts of climate change (alleviating symptoms) and also steps to more directly deal with reversing the changes (attacking the underlying disease).

There are parallels to this approach in the sustainment of a complex weapon system such as ICBMs. For instance, depot gyro test equipment may be on course to be completely useless within 10 years. A complete redesign and replacement program is needed, but in parallel there are steps that can be taken in depot processes to alleviate the problems that will start occurring in year 5.

Risk boards are sometimes used to track benefits and opportunities as well. And there are benefits occurring due to increased CO_2 levels world-wide (new trade routes, more foliage, etc.) and mitigation plans should be aware when they tread on these benefits. In aerospace, this is analogous to the pilot who has become accustomed to the convenient (but never documented as a requirement) position of the radar screen in their cockpit only to be dismayed by the new navigation system which has been installed there without their involvement.

This sustainment risk board is not the decision-making / fund-allocating body. It is also not the climate scientists and modelers. It needs to understand both of those roles, but its role is "sustainment risk mitigation integrated long-range planning". The reason this group exists is to create and keep updated the complete list of prioritized risks associated with global climate change. It also provides useful information to the observing and assessing group, our current crop of climate change scientists and modelers. What kind of information would be useful? This kind: How well are your models helping the decision-makers? What areas of research will create the best and most compelling justifications for the pending long-range plans? What are better ways to combine data already available to help reach consensus?

Other sustainment roles that are suggested by the CSSMM are risk integrators who help midwife the identification of new risk statements, planners who can look at the whole list of suggested risk mitigation projects and combine them into integrated holistic plans, process guardians to help everyone stay on task, external inspector generals who can judge the work of the team, and IT experts and data administrators to help capture all data and models to make them available to anyone who needs them.

There are more roles. Perhaps the most important is a shared group role, a cadre of professionals with a mission[9]. How wide would this identity extend? Perhaps it extends beyond just the risk and planning board.

Examples of people currently involved in this issue and, therefore potential shared-experience "teammates", are politicians, journalists, scientists, and engineers. The following oversimplifies for clarity, that is, we assume there is such a thing as a "pure" politician or "pure" engineer and then assign certain strengths and weaknesses for each of these professions as motivation to ensure a balanced team.

Politicians are essential because they exercise the art of the possible and find ways to get local, national, and international actions realized. On the other hand, they are constrained by lack of deep knowledge and the need to get re-elected. Journalists are essential to get the word out to those with the ability to vote in favor of useful actions or politicians. Without accusing them of being partisan and dishonest (which there is a case for, but why go there?), they can be misinformed (there's a lot out there to know), manipulated (uncritically reprint press releases), or moronic (no background in science but think they understand) in their communication of the subject. Scientists are focused on creating broad theories based on data. On the other hand, they are not practiced in practical trade-offs. Engineers routinely deal with transforming scientific theories into practical systems, but are usually the ones creating the most exasperation as they ask endless questions and demand practical explanations after everyone else has made up their minds what to do. They are practiced in juggling solution spaces to determine the optimum solution, that is, formal or informal trade studies.

These trade studies factor in the opportunity costs associated with various paths, so it is greatly distressing to engineers to see in the press various global climate change activists touting a "new economics" that ignores resource allocation based on the theory that nations can simply print money to get projects funded[10].

It is left to the reader to continue this kind of analysis for other potential teammates (indeed for IT, process, and the entire CSSMM model). It is essential to understand and value individuals for their potential contributions and hedge (with other teammates) for their inherent limitations.

VI. Conclusions

The current approach of climate scientists and modelers working with politicians to solve the global climate change problem is not effective. The solution suggested by the CSSMM is to create the category of sustainers working together in a sustainment team to take the insights from the scientists and modelers and, using a sustainment risk system, create executable long-range plans to be presented to the politicians for approval by the central government apparatus or the taxpayers depending on the political system.

Summary of insights

1. The mission is "Ensure survival of the human species in a clean environment over centuries"
2. The system is The Solar System but we can focus most efforts on the biosphere and sun
3. The readiness factors are Anti-pollution, Species Diversity, Biosphere Energy Management, Global Defense
4. The decision-makers are the citizens (or despots in non-democratic states)
5. The observers are the climate scientists and modelers
6. A sustainment risk board is key to transforming knowledge to action[11]

Comparing this problem of controlling the global climate to the CSSMM to reveal insights is not complete in a 4,000-word paper. Further insights are possible. Execution of this concept will require even more revisiting and refinement. However, the CSSMM brings structure to the continual solving of the global climate problem.

In addition, this paper should help bring clarity to the increasing pressure from some membership[12] for AIAA to establish a position on global climate change. It is my contention that AIAA can best serve the community and its members by explaining and reminding (respectively) the best engineering approaches to major issues. But first, we must understand this approach to sustainment ourselves.

And one final question for future discussion. How do you create and maintain a professional sustainment cadre? What institution has the responsibility to create it, staff it, police it, keep it going…sustain it?

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[1] See charlesvono.com and follow the first menu item to "Presentations and Publications" to download full papers and presentations. Or go to AIAA's ARC and enter author: Vono. Start with Vono, Charles, "Fundamentals of Weapon System Sustainment", AIAA SciTech 2016, January 2016

[2] International Council on Systems Engineering (INCOSE)'s Systems Engineering Body of Knowledge website (SEBoKwiki.org). See the glossary.

[3] Vono, "The Rise of Long-lived Complex Systems", AIAA SPACE 2017, Orlando, Florida, 12-14 Sep 17

[4] Was it because soldiers with mild strains of the virus were left in the trenches while those with severe forms were sent home? Did the virus further mutate in response to the likelihood of sudden, violent death in the trenches?

[5] About 0.1 W/m2 *steady-state* warming from the Earth's core versus about 1.6 W/m2 *additional* heat attributed to an increase in greenhouse gases. Methods needed to achieve even this simple comparison are sufficiently complex to enable skeptics to find points of disagreement. Perhaps the best way to deal with individuals who seem too skeptical about global climate change is to encourage the individuals who are attempting the scientific method and ignore those who have no concept of the method. Without getting into atmospheric layers and other details, the sun contributes in the neighborhood of 1,000 W/m2.

[6] An outstanding leader in the sustainment of ICBMs often says: "You are not finished designing your fix until you have uncovered all the unexpected consequences of your well-intentioned actions." For instance, sulpher dioxide will likely reignite our acid rain crisis of the 1970s and 1980s which was largely resolved with clean air legislation in the 1990s.

[7] It's not like we could consult the design engineer or look at the design documents.

[8] Vono, "First Steps in Implementing Weapon System Sustainment Model", AIAA SciTech 2017, Grapevine, TX, 9–13 Jan 17.

[9] Vono, "Sustainment Organizations: People and Teams", AIAA SciTech, Kissimmee, FL 8-12 Jan 18.

[10] For instance, David Roberts writing for Vox in March 2018, Matthew Rozsa writing for Salon.com September 2019, and David Rotman writing for Technology Review April 2019.

[11] Perhaps composed of technical systems management experts in cooperating universities world-wide?

[12] For instance, AIAA Engage Open Forum discussions.