Satellite Testing: Test Results Database and Python GUI

The Applications of AI on NASA Satellites

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

For decades, NASA (National Aeronautics and Space Administration) engineers and contractors have been using a decades-old GUI (Graphical User Interface) to run modem tests for their satellites. These engineers are running tests on the modems to try and ensure that the satellites will run without failure for the upcoming Artemis missions at NASA. Those missions will attempt to revist the moon, as well as visit new places in our solar system (M. Smith, 2020, p. 1). My technical project was to attempt to create a more efficient and intuitive way for these engineers to store and access test results, to facilitate the necessary testing of these satellites. Armed with that experience, I am now going to critique how the CS courses at UVA have prepared me for this project, and potential ways in which the courses could be improved to help all CS students be more prepared for internship projects. On the other hand, my STS project will focus on the social issues that these satellites, combined with emerging technologies like AI (Artificial Intelligence), could pose to our society, and how the satellites are inherently performing political work in addition to their natural technical work. This political work, sometimes unintentionally, also marginalizes certain groups, countries, etc., while privileging others. The problem that I am attempting to understand, outline, and propose a solution for, is how satellite technology should be handled going forward, both from a technical persepective as well as a social perspective. Both of these cases, one technical, the other social, are needed to address the sociotechnical challenge of handling satellite technology moving forward.

Technical Project

In order to critique UVA's CS curriculum, I must first describe my experiences during my NASA internship, which will help illustrate why changes are necessary. Without delving too much into proprietary or government sensitive information, my research during the early stages of the project mostly involved understanding TDRS (Tracking and Data Relay Satellites) as a whole, and more specifically the capabilities and specific tests run on the ground station modems. These modems and satellites currently support the Mars missions, and the testing my team was working on was for the upcoming Artemis missions. Specifically, regarding the ground station modems, some of the most important test parameters include polarization, carrier modulation, carrier data rate, subcarrier modulation, and decoding, seen in Figure 1 below.

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	22.8 dB/K (clear sky & 41° elevation angle)
Polarization	RHC or LHC
Antenna Beamwidth	0.85 deg
Antenna Gain	45.8 dBi
Carrier Modulation	PM/PCM, FM/PCM, BPSK, or QPSK / OQPSK
Modulation Index	PM: 0.2 – 2.8 Radians (peak)
Carrier Data Rate (High Rate Telemetry Channel)	1 Kbps – 10 Mbps (FM/PCM) 100 bps – 20 Mbps (PM/PCM, BPSK, OQPSK) 1 Kbps – 40 Mbps (QPSK) [< 20 Mbps per channel]
Carrier Data Format	NRZ-L, M or S, Biϕ-L, M or S; DM-M or S; DBP-M or S; RNRZ
Subcarrier Frequency	5 kHz – 2 MHz
Subcarrier Modulation	PSK, BPSK, PCM/PM for high BW telemetry
Subcarrier Data Rate	100 bps – 600 Kbps
Subcarrier Data Format	Passes all NRZ or Biϕ or DM
Decoding	Derandomization, Viterbi and/or Reed-Solomon (Ref Para 1.3 s)

Figure 11.6: S-band Telemetry Characteristics for the WG1 Antenna at NASA Wallops Flight Facility.
Credits: NASA

Figure 1: Modem Parameters

After I had fully understood these tests and what their input parameters were and output data was, I had to begin to plan out how my database and GUI would function and interact with each other.

Because my end goal was an isolated product, which would be later incorporated into a larger project, I decided to use a Microsoft Access database over something much more powerful databases like a standard SQL (Structured Query Language) database purely for simplicity. While Microsoft Access databases are not like databases typically used in industry, it can still be queried by SQL commands, which would allow for this prototype to be easily transitioned into a different SQL database. As far as the actual design of the database itself, I came up with multiple different approaches. One approach had a different table for each different test type, while other approaches had different tables based off other input parameters (test performer, date, etc.). After consulting with the engineers, I deemed that the approach with different tables for different test types would be the most optimized approach, as that would be their most frequent queries.

Due to my familiarity with Python and Python Pandas from my classes at UVA, and also because that was the only programming language that any of the engineers had experience in, that was the language and library I chose for the GUI code. I first had to design a high-level diagram (similar to a UML diagram) which would help determine how many different tabs the GUI would have, as well as which of the other tabs each tab would interact with.

As previously mentioned, the classes I've taken at UVA did a good job of preparing me for the python/coding aspects of my project; however, a large hole that I, and others, have noticed when beginning real world issues is the lack of database instruction that we receive. There are some optional classes, like Database Systems, which are extremely useful for a project like the one I did. These courses are mostly electives (and upper-level ones at that), which many students either don't take at all, or don't take until their last year of schooling, after they've already had multiple internships.

In order to better prepare students for experiental learning events like mine, I believe that the UVA CS curriculum should be changed to include mentions of basic database concepts much earlier in the program. In addition, the curriculum should also place a higher emphasis on teaching agile methodologies, which nearly every software development team in the country uses, and which is only really mentioned in Advanced Software Design.

An example of a professor who recognized some of these short comings is Saul Greenberg. In his book, *Embedding a Design Studio Course in a Conventional Computer*

Science Program, Greenberg notes how "The problem is: how can we pass on the best practices of design studios within traditional programs that follow a standard lecture/tutorial format" (2007, p. 30). In this section, Greenberg lays out one of the problems that I noted with the agile methodologies earlier.

Evidence will need to be found to propose improvements to the CS curriculum. As mentioned above, some CS professors, like Greenberg, have noticed the issues with common CS curriculums like UVA, so gathering some of their syllabuses, among other class materials, would help to provide evidence for why these improvements are necessary. Likewise, those syllabuses and materials could be contrasted with the current UVA CS syllabuses, which, with the exception of Advanced Software Development mentioned above, do not mention these important work skills which I believe need to be added to the curriculum.

While the CS program here does an excellent job of preparing students with many skills like algorithms, terminal navigation, etc. (indeed, prepared seemingly much better than many of my coworkers seem to have been), many of the "softer" skills that CS graduates also need are severely lacking.

STS Project

While I was working on my satellite testing project, it became evident just how powerful of a tool satellites are. In addition to their current capabilities, breakthroughs in AI, machine learning, and other computer science branches, which I have been learning about in my classes, are enhancing their capabilities. Viewing this potential through a social lense allows me to put my technical project in perspective.

One of the newest ermerging technologies, which has many implications for satellite programming, is artificial intelligence. Using artificial intelligence technology and satellite technology, tasks like identifying people can be seamlessly automated. One such technology utilizing AI is MetaConstellation. A user of MetaConstellation can "Ask a real world question and MetaConstellation determines the optimal mix of sensors to answer that question" (Palantir, 2022). In their piece, *Artificial intelligence for satellite communication: A review*, Fares Fourati and Mohamed-Slim Alouini note that, "In particular, the application of AI to a wide variety of satellite communication aspects has demonstrated excellent potential, including beam-hopping, anti-jamming, network traffic forecasting, channel modeling, telemetry mining, ionospheric scintillation detecting, interference managing, remote sensing, behavior modeling, space-air-ground integrating, and energy managing" (2021). These applications of satellites and AI could have a profound impact on the future of many different technological fronts.

I will be using Technological Politics to discuss the social and political work that satellite technology performs by analyzing the war in Ukraine and the use of MetaConstellation. MetaConstellation, developed by the contractor Palantir, is, "allows a user to specify a time and ground location—say, where you recently launched a HIMARS strike against a Russian tank company—and get an AI-assisted search of all the relevant data gathered by passing satellites, whether radio signals, thermal imagery, or aerial photos" (Tucker, 2021). The technology of satellites formed extremely successfully, itinitally due to a heavy demand for space exploration. However, as the uses for the technology have evolved, so has the technology itself. During this evolution, it has taken on the responsibility of performing social and political work in addition to its designed technical work. Drawing on the ideas of Technological Politics, I argue that satellites privilege some and marginalize others.

One such instance which clearly displays this effect would be a paper like *Automatic Target Detection in Satellite Images using Deep Learning*. In this paper and many others, the concept that “Automatic detection of military targets such as oil tanks, aircrafts, artillery, etc. in high resolution satellite imagery has great significance in military applications” (Khan et al, 2017, p. 1) illustrates the intense political work that satellites perform. Military actions are, by definition, extremely political in nature, and these satellites, whose initial goal was also in some ways political (space exploration), perform work which can heavily marginalize groups who don’t have access to these satellites. While MetaConstellation is currently being used in the war on Ukraine against Russians, which are in many ways not marginalized, it is easy to see how this technology could be used in other social and political ways on marginalized groups who do not have access to this technology. Many other works, like *A hierarchical oil depot detector in highresolution images with false detection control* and *Artificial Intelligence Based Mobile Tracking and Antenna Pointing in Satellite-Terrestrial Network* illustrate this point as well.

In regard to AI and satellites specifically, recent research exemplifies the political power of the satellite. “Moral objections to AI by contractor-technicians in the US may slow new development by the DOD” (Wilson, 2020). Because of the political nature of satellites and AI, the US is disadvantaged compared to countries like Russia and China which do not object to the political power of this technology.

A technology which performs technical work simulataneously can also be performing political work, the crux of the technological politics framework. As Landon Winner points out, “is neither correct nor insightful to say, "Someone intended to do somebody else harm." Rather, one must say that the technological deck has been stacked long in advance to favor certain social interests, and that some people were bound to receive a better hand than other” (Winner, 1980, p. 6). Technology such as satellites, which were designed to benefit a certain group, certainly favors certain social interests, and thus it can be said that this technology performs political work. Thusly, when developing newer technologies which empower satellites even more, like AI and machine learning, it is important to consider the social implications this will have, as this will only empower the satellites to have more political power. Groups like the American Military are specifically priveleged, using MetaConstellation in the war in Ukraine while groups without access to AI satellite technologies like MetaConstellation, are marginalized.

The focus on AI development in the past 5 years which is greatly empowering satellite technology allows me to see how the political and social power of satellites has also been strengethened. In order to fully answer how these satellites, combined with AI, perform political and social work, I am likely going to need to see other applications besides just the war in Ukraine in which AI like MetaConstellation is being used, such as spying on marginalized groups.

Conclusion

In order for the Artemis missions, which will begin with the US returning to the moon, to happen, satellite and modem testing needs to happen to ensure the safety of the astronauts. My technical project, and the future improvements it can facilitate, helped to make that happen. Throughout that project, I was able to discover some of the major gaps in the UVA CS curriculum, allowing me to critique it. After that experiencal learning event, I am able to look at satellite technology from a different perspective, learning what societal impacts such a powerful technology can have. The problem of trying to create a powerful technology while also being mindful of the societal effects it can have is a challenge that requires engineers to make thoughtful design decisions. In addition to the societal work this satellite technology has, engineers must also consider the political work their inventions can perform. Combining aspects from both the technical project and STS project allows me to solve the sociotechnical problem of satellite technology moving forward.

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