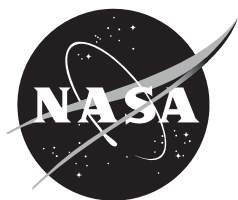


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Three Dimensional Lightning Launch Commit Criteria Visualization Tool

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May 2014

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Executive Summary

Customer: NASA's Launch Services Program (LSP) and Space Launch System (SLS) program

Lightning occurrence too close to a NASA LSP or future SLS program launch vehicle in flight would have disastrous results. The sensitive electronics on the vehicle could be damaged to the point of causing an anomalous flight path and ultimate destruction of the vehicle and payload.

According to 45th Weather Squadron (45 WS) Lightning Launch Commit Criteria (LLCC), a vehicle cannot launch if lightning is within 10 NM of its pre-determined flight path. The 45 WS Launch Weather Officers (LWOs) evaluate this LLCC for their launch customers to ensure the safety of the vehicle in flight. Currently, the LWOs conduct a subjective analysis of the distance between lightning and the flight path using data from different display systems. A 3-D display in which the lightning data and flight path are together would greatly reduce the ambiguity in evaluating this LLCC. It would give the LWOs and launch directors more confidence in whether a GO or NO GO for launch should be issued. When lightning appears close to the path, the LWOs likely err on the side of conservatism and deem the lightning to be within 10 NM. This would cause a costly delay or scrub. If the LWOs can determine with a strong level of certainty that the lightning is beyond 10 NM, launch availability would increase without compromising safety of the vehicle, payload or, in the future, astronauts.

The AMU was tasked to conduct a market research of commercial, government, and open source software that might be able to ingest and display the 3-D lightning data from the KSC Lightning Mapping Array, the 45th Space Wing Weather Surveillance Radar (WSR), the National Weather Service in Melbourne WSR – 1988 Doppler, and the vehicle flight path data so that all can be visualized together. To accomplish this, the AMU conducted Internet searches for potential software candidates and interviewed software developers.

None of the available off-the-shelf software had a 3-D capability that could display all of the data in a single visualization. The AMU determined there are two viable software packages that could satisfy the 45 WS requirement with further development and recommends the KSC Weather Office follow-up with both organizations to request development costs.

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1. Introduction

Lightning occurrence too close to a NASA Launch Services Program (LSP) or future Space Launch System (SLS) program launch vehicle in flight would have disastrous results. The sensitive electronics on the vehicle could be damaged to the point of causing an anomalous flight path and ultimate destruction of the vehicle and payload.

According to 45th Weather Squadron (45 WS) Lightning Launch Commit Criteria (LLCC), a vehicle cannot launch if lightning is within 10 NM of its pre-determined flight path. The 45 WS Launch Weather Officers (LWOs) evaluate this LLCC for their launch customers to ensure the safety of the vehicle in flight. Currently, the LWOs conduct a subjective analysis of the distance between lightning and the flight path using data from different display systems. A 3-D display in which the lightning data and flight path are together would greatly reduce the ambiguity in evaluating this LLCC. It would give the LWOs and launch directors more confidence in whether a GO or NO GO for launch should be issued. When lightning appears close to the path, the LWOs likely err on the side of conservatism and deem the lightning to be within 10 NM. This would cause a costly delay or scrub. If the LWOs can determine with a strong level of certainty that the lightning is beyond 10 NM, launch availability would increase without compromising safety of the vehicle, payload or, in the future, astronauts.

Initially, this task contained two goals: 1) develop a 3-D lightning event location algorithm that determines the probability that an event is within 10 NM of a launch vehicle flight path, and 2) incorporate the algorithm into a 3-D graphical user interface (GUI) that will ingest and display lightning events from the Kennedy Space Center (KSC) new Lightning Mapping Array (LMA) in relation to the launch vehicle flight path and display the probability of the event being within 10 NM of the flight path. Meeting these two goals would provide more objectivity than the current analysis and would provide the 45 WS LWOs and range customers with a quantitative risk of lightning to the flight path. Bringing all of these elements together in one display would decrease the time used to make the analysis and increase the confidence in the analysis results.

During the September 2013 AMU Tasking Meeting, the AMU customers decided this task needed to be reduced in scope and completed in phases due to the reduced funding of the AMU contract. Therefore, the AMU was tasked to conduct a market research of commercial, government, and open source software that might be able to ingest and display the 3-D lightning data from the KSC LMA, the 45th Space Wing (45 SW) Weather Surveillance Radar (WSR), the National Weather Service in Melbourne Weather Surveillance Radar – 1988 Doppler (WSR-88D), and the vehicle flight path data so that all can be visualized together. To accomplish this, the AMU conducted Internet searches for potential software candidates and interviewed software developers.

2. Software Search

The AMU conducted the market research by using a keyword Internet search for software that could potentially ingest and display the data types. The results of this search yielded software in four categories from multiple sources as shown in Table 1. Upon completion of Internet searches, the AMU contacted software developers via e-mail or talked to them directly while attending the 93rd American Meteorological Society (AMS) Annual Meeting in Atlanta, Georgia, from 2–6 February 2014. They found that none of the candidate software could meet the data display requirement without some development.

Based on current capability to visualize meteorological parameters and vehicle flight path, the two most likely candidate software packages include Omni[®], developed and sold by Baron Services, Inc. (hereafter Baron), and the Real Time Mission Monitor (RTMM), developed by

NASA Marshall Space Flight Center (MSFC), to track and monitor assets during Earth science research airborne field deployments (Goodman et al. 2011).

Table 1. Summary of candidate software discovered from the Internet keyword search.

Category	Source	Software Name	3-D Capable
Commercial	Baron Services, Inc.	Omni	Yes
		OmniWxTrac	No
	Gibson Ridge Software, LLC	GR2Analyst	Yes
	AVS	OpenViz	Yes
		AVS Express	Yes
	Impressum	Ninjo Workstation	No
	Ultra Electronics	ProLogic	Yes
Weather Decision Technologies	GIS Weather Services	No	
Government	NCAR	NCAR Graphics/Vislab	Yes
	NWS	AWIPS	Yes
	USAF	FalconView Weather	In development
	NASA	Real Time Mission Monitor	No
Open Source	Kitware	ParaView	Yes
University	Georgia Tech	VGIS	Yes

2.1 Omni Software

Baron states that Omni is “Capable of depicting multiple layered datasets from any available source simultaneously” and that “Omni enables full integration of meteorological observations, from radar and satellite imagery to live sensors, cameras, forecast modeling and much more.” Omni is also capable of displaying 3-D volumetric radar imagery, integrating almost any kind of native sensor format, and tracking mobile assets equipped with GPS-enabled devices. The AMU talked to Baron Executive Vice President and Chief Development Officer Bob Dreisward at the AMS meeting about the requirements and he stated that Omni could possibly display the data but not without development. He recommended NASA contact him to request a quote for the development costs.

2.2 RTMM Software

The RTMM is described as “a situational awareness tool that integrates satellite, airborne and surface data sets; weather information; model and forecast outputs; and vehicle state data (e.g., aircraft navigation, satellite tracks and instrument field-of-views) for field experiment management” (Blakeslee et al. 2007). The AMU could not find any references to a 3-D version of RTMM but, in its current state, it is capable of displaying the required data types: WSR-88D reflectivity images, C-band weather radar reflectivities (e.g., the 45 SW WSR), multiple lightning strike networks including LMAs, and vehicle tracks (aircraft or vertical launch). The RTMM uses a Google Earth plug-in application programming interface (API) giving it an intuitive and familiar

user interface (Figure 1). Using the API allows users to run the RTMM application in a web browser instead of having to install the Google Earth standalone application on their computer.

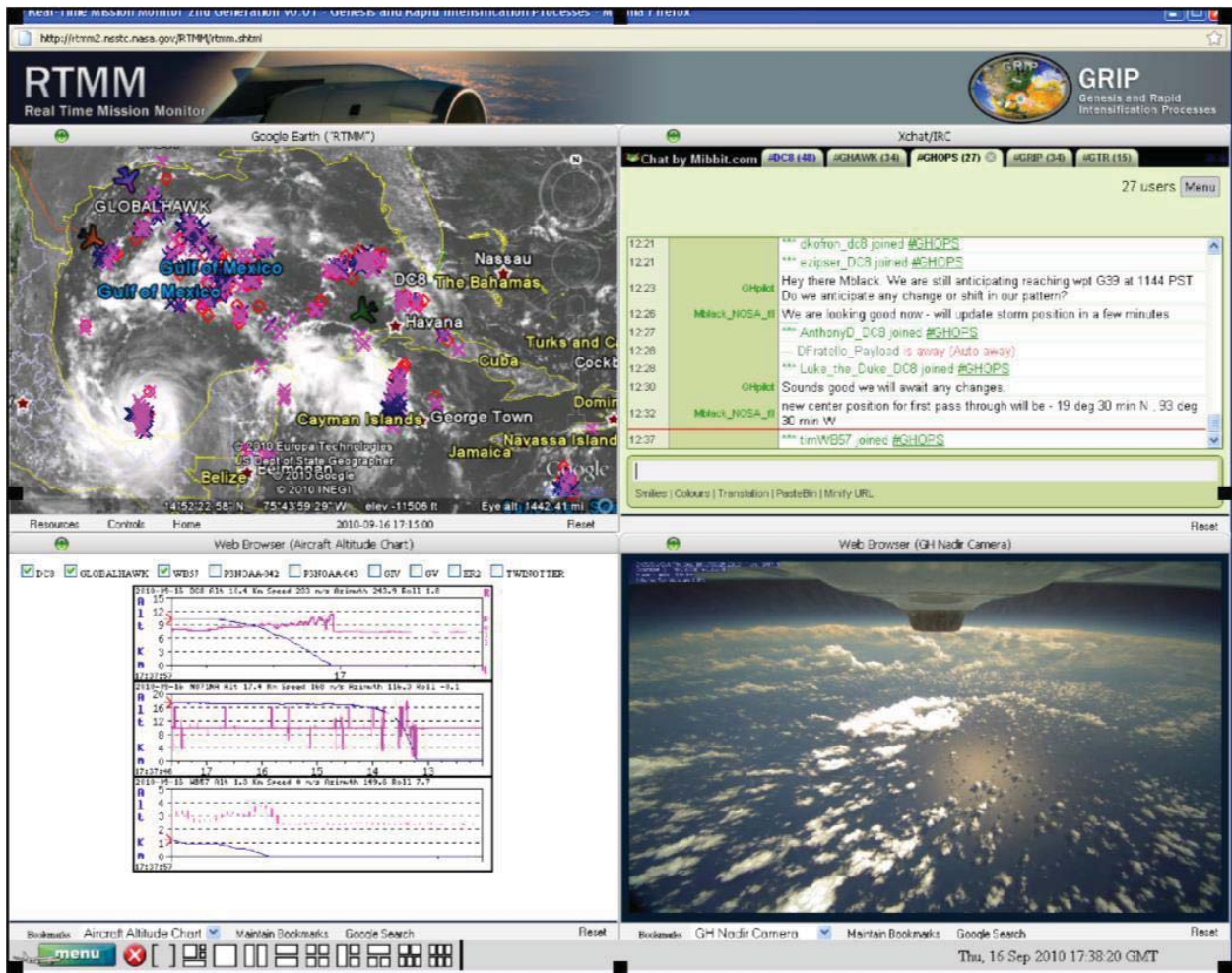


Figure 1. Four-panel RTMM screen depicting (upper left): three aircraft with lightning strikes in magenta; (upper right): XChat discussion of Global Hawk waypoint timing; (lower left): aircraft altitude charts; (lower right): nadir camera view from the belly of the Global Hawk (Figure 3 in Goodman et al. 2011).

3. Data Formats

The format of each data type must be known in order to determine if the software will be able to visualize the data. The AMU asked the KSC Weather Office for assistance acquiring the data format for the KSC LMA. They provided a contact, Mr. Bill Rison at the New Mexico Institute of Mining and Technology (New Mexico Tech), who provided a sample output file from an LMA similar to the one being installed at KSC along with an explanation of the data format. The data are output as a compressed and zipped American Standard Code for Information Interchange (ASCII) text file. The ASCII file contains rows of LMA source data including time, latitude, longitude, altitude, goodness of fit, source power, and a mask indicating which of the LMA stations detected the source. Mr. Rison also provided a uniform resource locator (URL) for a New Mexico Tech server. The URL is <http://lightning.nmt.edu/sitetestlma/> and it displays real-time and archived plots of LMA data as shown in Figure 2.

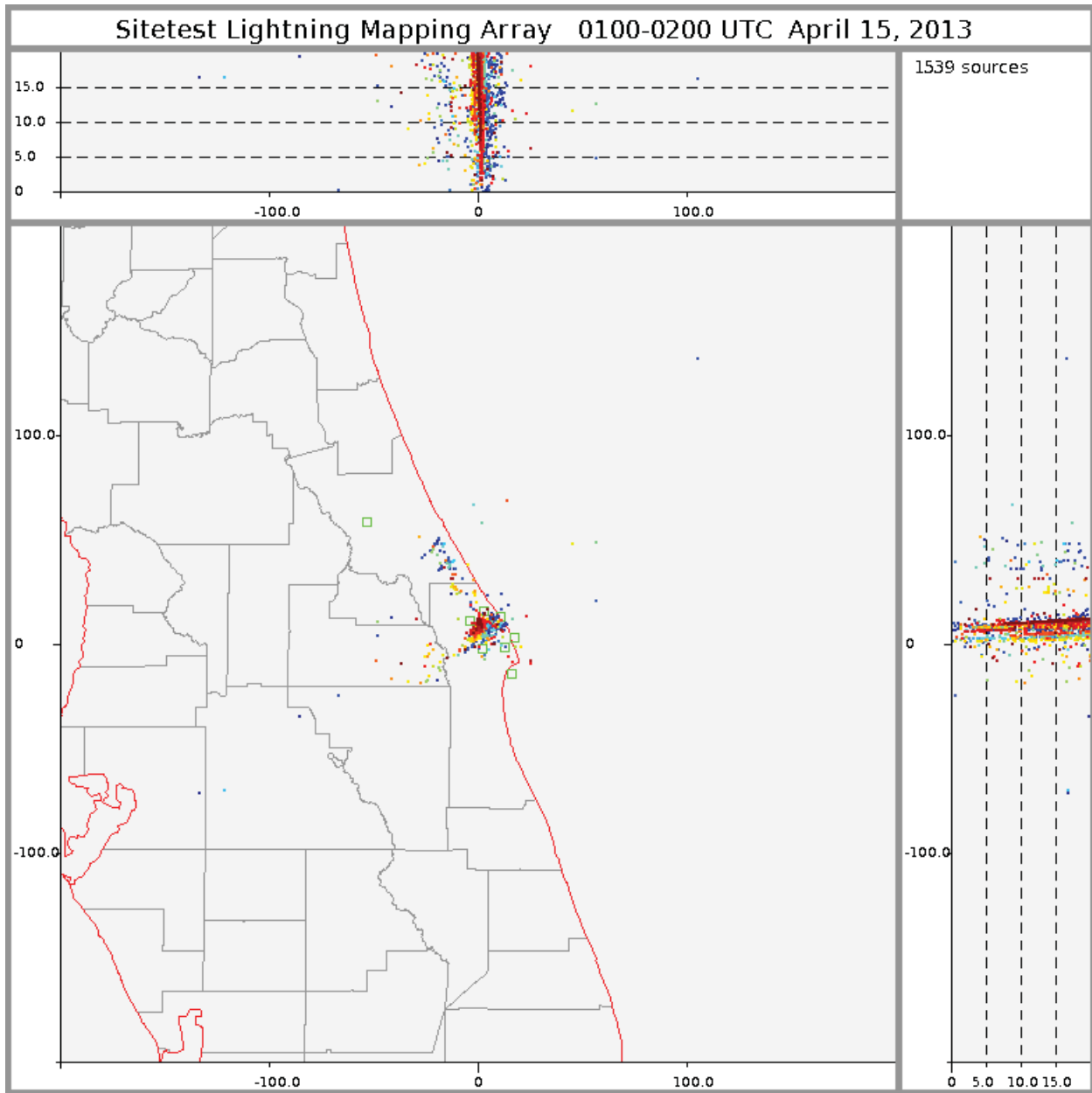


Figure 2. Plot of LMA points from 15 April 2013 in the KSC test network that was operating from fall 2012 to spring 2013.

Knowing the LMA format and that the 45 WS and AMU already have GR2Analyst software, The AMU contacted Mr. Mike Gibson of Gibson Ridge Software to inquire whether GR2Analyst could ingest and display the LMA data into the software's 3-D Volume Explorer. Mr. Gibson indicated that GR2Analyst uses slices of volumetric radar data instead of 3-D objects. He stated it would be difficult, but not impossible, to display 3-D objects such as LMA points and the vehicle track with the radar data, but there would be issues where the lightning and track data intersect with the radar reflectivity causing them to appear in front of or behind the reflectivity when they are really coincident with it. Figure 3 shows a 3-D depiction of anvil cloud from a thunderstorm west of KSC from the Melbourne WSR-88D radar generated by the AMU GR2Analyst software.

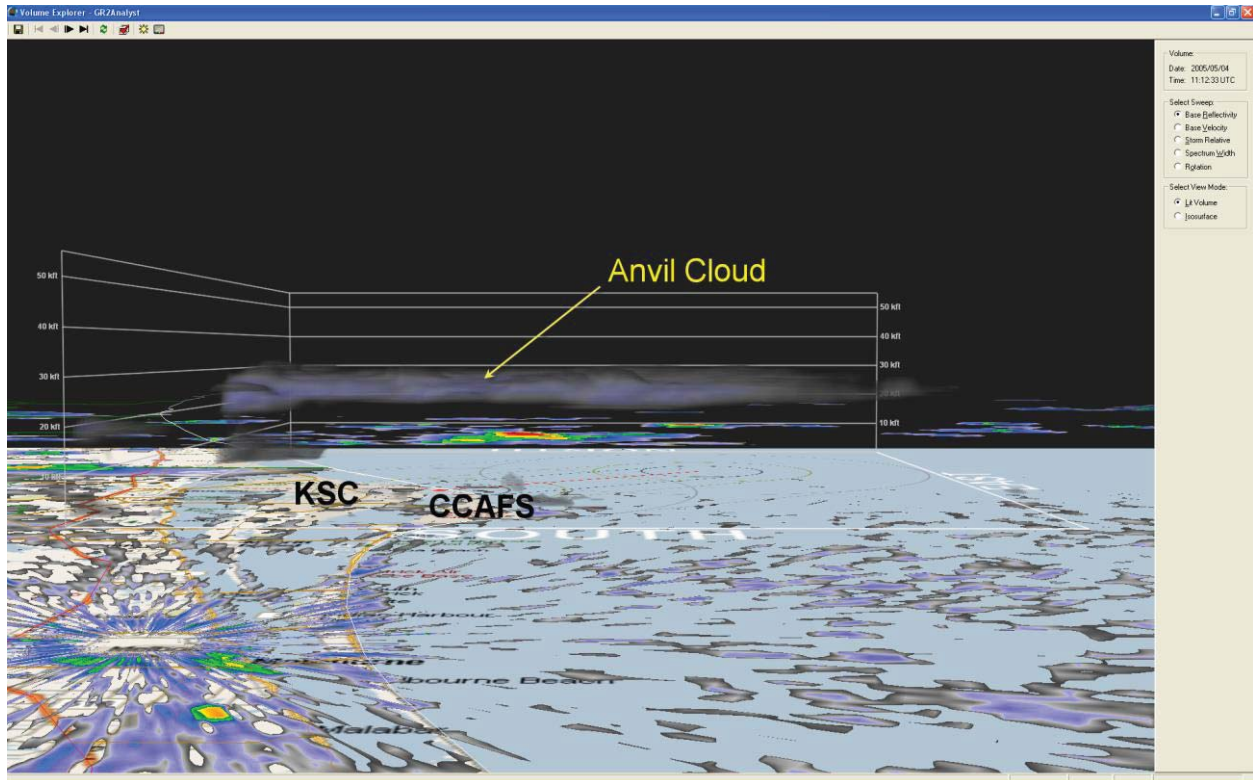


Figure 3. Depiction of anvil cloud from a thunderstorm west of KSC on 4 May 2006 in the GR2Analyst Volume Explorer.

4. KSC Lightning Mapping Array

At this time, the KSC LMA is still under construction and no data are available. Dr. Bauman was told by KSC Ground Processing Directorate personnel that once the LMA network is complete the data will terminate in the KSC Data Center and will not be provided to the 45 SW. The data will, therefore, not be available to populate a computer system in Range Weather Operations at CCAFS. It would be up the 45 SW to coordinate and fund the infrastructure to get the data to CCAFS.

5. Recommendation

The AMU recommends the NASA KSC Weather Office follow-up with Baron and NASA/MSFC to request more information on these two candidate software packages to determine the development costs needed to meet the full 3-D data display requirements required by the 45 WS LWOs.

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- Goodman, M. H., R. Blakeslee, K. Regner, P. Meyer, and H. Conover, 2011: Coordinating Aircraft During NASA Airborne Science Field Campaigns. Earth Science Technology Forum, 21-23 June 2011, Pasadena, CA.

List of Acronyms

45 WS	45th Weather Squadron	LMA	Lightning Mapping Array
45 SW	45th Space Wing	LSP	Launch Services Program
API	Application Programming Interface	LWO	Launch Weather Officer
AMU	Applied Meteorology Unit	MSFC	Marshall Space Flight Center
ASCII	American Standard Code for Information Interchange	RTMM	Real Time Mission Monitor
CCAFS	Cape Canaveral Air Force Station	URL	Uniform Resource Locator
KSC	Kennedy Space Center	WSR	45th Space Wing Weather Surveillance Radar
LLCC	Lightning launch Commit Criteria	WSR-88D	Weather Surveillance Radar – 1988 Doppler

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