

Software Tool for Tracking & Mapping the NASA Orion AA-2 Test Flight Ejectable Data Recorders in Real Time

Software Tool for Tracking & Mapping the NASA Orion AA-2 Test Flight Ejectable Data Recorders in Real Time
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Introduction & Objectives

- NASA's ascent abort2 (AA-2) test flight took place off the coast of Florida (NASA Kennedy Space Center) on July 2, 2019

Software Tools

Customized Outlook Tabular Display:

Recorder ID	Time	Status	Latitude	Longitude	Altitude	Speed	Direction
101	07:00:00	OK	28.5	-80.5	10000	1000	090
102	07:00:05	OK	28.5	-80.5	10000	1000	090
103	07:00:10	OK	28.5	-80.5	10000	1000	090
104	07:00:15	OK	28.5	-80.5	10000	1000	090
105	07:00:20	OK	28.5	-80.5	10000	1000	090
106	07:00:25	OK	28.5	-80.5	10000	1000	090
107	07:00:30	OK	28.5	-80.5	10000	1000	090
108	07:00:35	OK	28.5	-80.5	10000	1000	090
109	07:00:40	OK	28.5	-80.5	10000	1000	090
110	07:00:45	OK	28.5	-80.5	10000	1000	090
111	07:00:50	OK	28.5	-80.5	10000	1000	090
112	07:00:55	OK	28.5	-80.5	10000	1000	090
113	07:01:00	OK	28.5	-80.5	10000	1000	090
114	07:01:05	OK	28.5	-80.5	10000	1000	090
115	07:01:10	OK	28.5	-80.5	10000	1000	090
116	07:01:15	OK	28.5	-80.5	10000	1000	090
117	07:01:20	OK	28.5	-80.5	10000	1000	090
118	07:01:25	OK	28.5	-80.5	10000	1000	090
119	07:01:30	OK	28.5	-80.5	10000	1000	090
120	07:01:35	OK	28.5	-80.5	10000	1000	090
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122	07:01:45	OK	28.5	-80.5	10000	1000	090
123	07:01:50	OK	28.5	-80.5	10000	1000	090
124	07:01:55	OK	28.5	-80.5	10000	1000	090
125	07:02:00	OK	28.5	-80.5	10000	1000	090
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130	07:02:25	OK	28.5	-80.5	10000	1000	090
131	07:02:30	OK	28.5	-80.5	10000	1000	090
132	07:02:35	OK	28.5	-80.5	10000	1000	090
133	07:02:40	OK	28.5	-80.5	10000	1000	090
134	07:02:45	OK	28.5	-80.5	10000	1000	090
135	07:02:50	OK	28.5	-80.5	10000	1000	090
136	07:02:55	OK	28.5	-80.5	10000	1000	090
137	07:03:00	OK	28.5	-80.5	10000	1000	090
138	07:03:05	OK	28.5	-80.5	10000	1000	090
139	07:03:10	OK	28.5	-80.5	10000	1000	090
140	07:03:15	OK	28.5	-80.5	10000	1000	090
141	07:03:20	OK	28.5	-80.5	10000	1000	090
142	07:03:25	OK	28.5	-80.5	10000	1000	090
143	07:03:30	OK	28.5	-80.5	10000	1000	090
144	07:03:35	OK	28.5	-80.5	10000	1000	090
145	07:03:40	OK	28.5	-80.5	10000	1000	090
146	07:03:45	OK	28.5	-80.5	10000	1000	090
147	07:03:50	OK	28.5	-80.5	10000	1000	090
148	07:03:55	OK	28.5	-80.5	10000	1000	090
149	07:04:00	OK	28.5	-80.5	10000	1000	090
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152	07:04:15	OK	28.5	-80.5	10000	1000	090
153	07:04:20	OK	28.5	-80.5	10000	1000	090
154	07:04:25	OK	28.5	-80.5	10000	1000	090
155	07:04:30	OK	28.5	-80.5	10000	1000	090
156	07:04:35	OK	28.5	-80.5	10000	1000	090
157	07:04:40	OK	28.5	-80.5	10000	1000	090
158	07:04:45	OK	28.5	-80.5	10000	1000	090
159	07:04:50	OK	28.5	-80.5	10000	1000	090
160	07:04:55	OK	28.5	-80.5	10000	1000	090
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163	07:05:10	OK	28.5	-80.5	10000	1000	090
164	07:05:15	OK	28.5	-80.5	10000	1000	090
165	07:05:20	OK	28.5	-80.5	10000	1000	090
166	07:05:25	OK	28.5	-80.5	10000	1000	090
167	07:05:30	OK	28.5	-80.5	10000	1000	090
168	07:05:35	OK	28.5	-80.5	10000	1000	090
169	07:05:40	OK	28.5	-80.5	10000	1000	090
170	07:05:45	OK	28.5	-80.5	10000	1000	090
171	07:05:50	OK	28.5	-80.5	10000	1000	090
172	07:05:55	OK	28.5	-80.5	10000	1000	090
173	07:06:00	OK	28.5	-80.5	10000	1000	090
174	07:06:05	OK	28.5	-80.5	10000	1000	090
175	07:06:10	OK	28.5	-80.5	10000	1000	090
176	07:06:15	OK	28.5	-80.5	10000	1000	090
177	07:06:20	OK	28.5	-80.5	10000	1000	090
178	07:06:25	OK	28.5	-80.5	10000	1000	090
179	07:06:30	OK	28.5	-80.5	10000	1000	090
180	07:06:35	OK	28.5	-80.5	10000	1000	090
181	07:06:40	OK	28.5	-80.5	10000	1000	090
182	07:06:45	OK	28.5	-80.5	10000	1000	090
183	07:06:50	OK	28.5	-80.5	10000	1000	090
184	07:06:55	OK	28.5	-80.5	10000	1000	090
185	07:07:00	OK	28.5	-80.5	10000	1000	090
186	07:07:05	OK	28.5	-80.5	10000	1000	090
187	07:07:10	OK	28.5	-80.5	10000	1000	090
188	07:07:15	OK	28.5	-80.5	10000	1000	090
189	07:07:20	OK	28.5	-80.5	10000	1000	090
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191	07:07:30	OK	28.5	-80.5	10000	1000	090
192	07:07:35	OK	28.5	-80.5	10000	1000	090
193	07:07:40	OK	28.5	-80.5	10000	1000	090
194	07:07:45	OK	28.5	-80.5	10000	1000	090
195	07:07:50	OK	28.5	-80.5	10000	1000	090
196	07:07:55	OK	28.5	-80.5	10000	1000	090
197	07:08:00	OK	28.5	-80.5	10000	1000	090
198	07:08:05	OK	28.5	-80.5	10000	1000	090
199	07:08:10	OK	28.5	-80.5	10000	1000	090
200	07:08:15	OK	28.5	-80.5	10000	1000	090

Google Earth Display:

Results Summary

Overall Results:

- Total of 200 RRs ejected
- 13 RRs transmitted data:
 - Only 6 RRs transmitted valid data prior to being found & recovered
 - 3 RRs transmitted enough data points to generate valid tracklines & location prediction estimates

Methodology

"Ejectable Data Recorder (EDR) Season Tracking Software" Design Architecture

Conclusions

- Translation of binary data into Google Earth (GE) mapping tool allowed for rapid & seamless spatial arrangement of vital information
- The use of GE allowed for depicting drift patterns, which aided recovery vessel operations
- Prediction tool provided an additional resource for locating EDRs
- Software can be customized for supporting multiple Inidium (or similar) applications that require real-time

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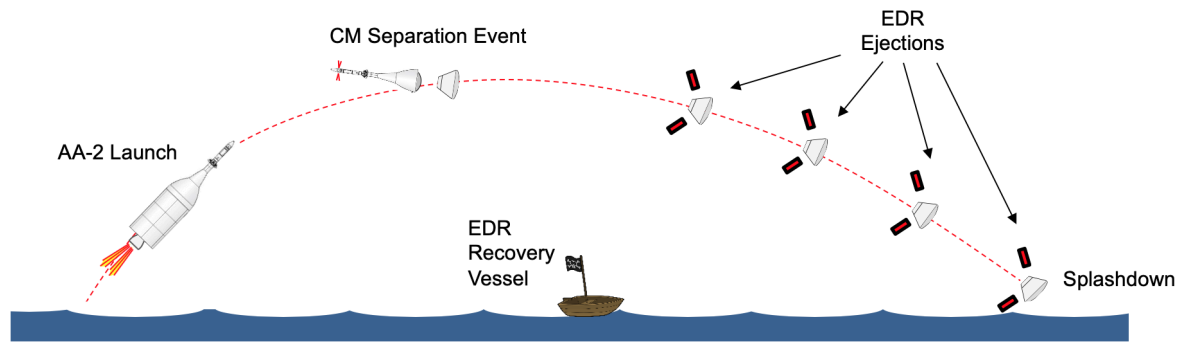


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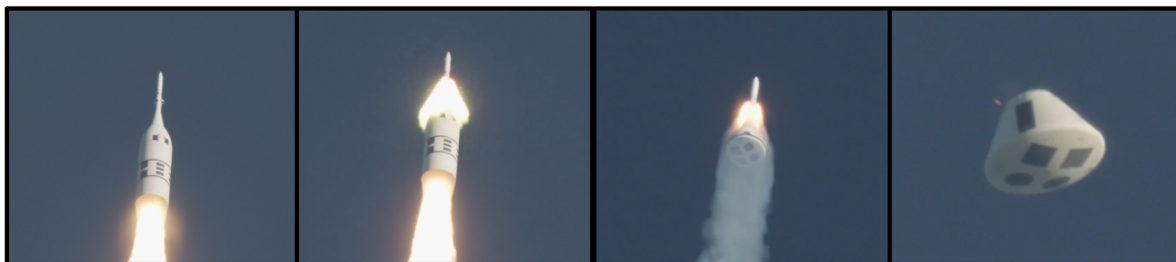
INTRODUCTION & OBJECTIVES

- NASA Ascent Abort 2 (AA-2) test flight took place off the coast of Florida (NASA Kennedy Space Center) on July 2, 2019



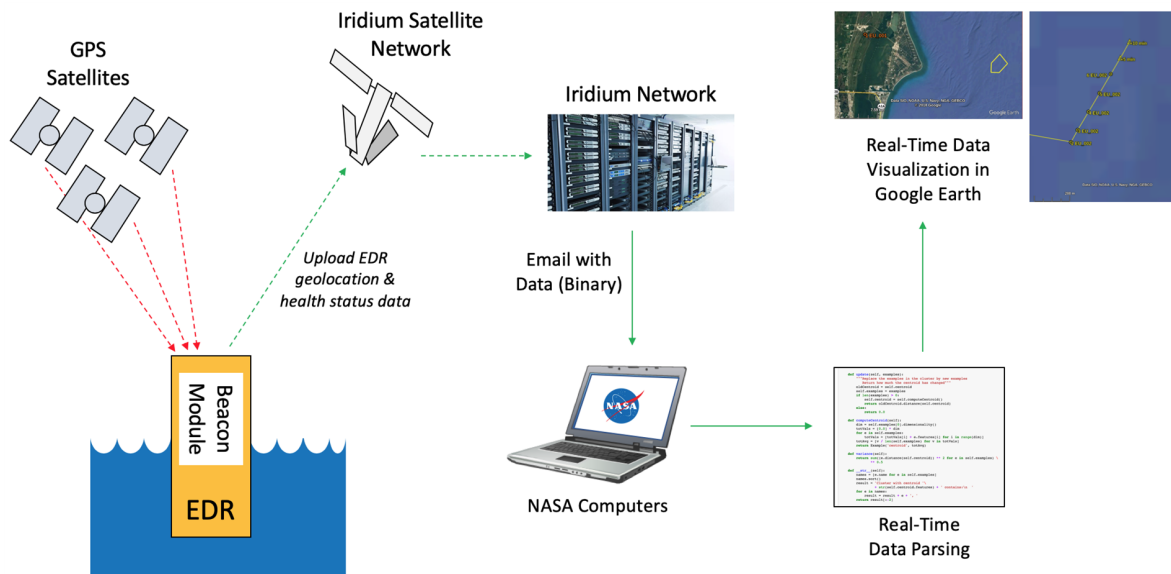
- Instrumentation data was recorded onboard by means of 12 customized buoyant Ejectable Data Recorders (EDRs)
 - EDRs containing geolocation beacons were activated sequentially following the separation event. Each EDR contained:
 - GPS Antenna
 - Iridium Antenna
 - GPS Receiver/Iridium Short Burst Data (SBD) Modem
 - Power Switch
 - Data Recorder Hardware
 - Battery (>14 hrs autonomy)
- EDRs were pre-programmed to transmit geolocation data every 5 minutes (approx.)
- Tracking & ocean surface recovery operations began after Crew Module (CM) splashdown
- Objectives:
 - Develop software tools to automatically monitor in real-time:
 - Individual EDR beacon health status
 - Recover geolocation information
 - Map individual EDR locations and tracklines
 - Predict the locations of each EDR at t+5 and t+10 minutes based on the last 2 known locations
 - Leverage off existing open-source tools
 - Achieve full data display flexibility for EDR tracking application:
 - Customizable data point names
 - Customizable data point labels

- Selection of data to be visualized



METHODOLOGY

1. "EDR Beacon Tracking Software" Design Architecture:



2. Software Development & Implementation:

Relied 100% on open-source software

- Email & Attachment Management: FiltaQuilla (Mozilla Thunderbird add-on for saving Iridium SBD binary files)

- Customized Data Processing & Extraction:

- Linux programming shells
- Python v2.7.10
 - Python libraries
 - Colorama
 - Termcolor
 - Python-dateutil
 - Pypi Pyproj
 - Pypi LatLon
 - Numpy

---> tools extracted Iridium SBD data into an ASCII log files

- Data Visualization: Google Earth
 - Excellent data display flexibility
 - Use of dynamic KML file generation for each EDR
 - Locations were updated in real-time
 - Products generated:
 1. Latest reported location & Label
 2. Health status summary
 3. Derived trajectory (heading & speed)
 4. Derived location predictions (t+5min & t+10min)

- Recovery Operations: Relayed geolocation data to recovery vessels for EDR retrieval

SOFTWARE TOOLS

Customized Quicklook Tabular Display:

EDR Real-Time Status & Data Monitor

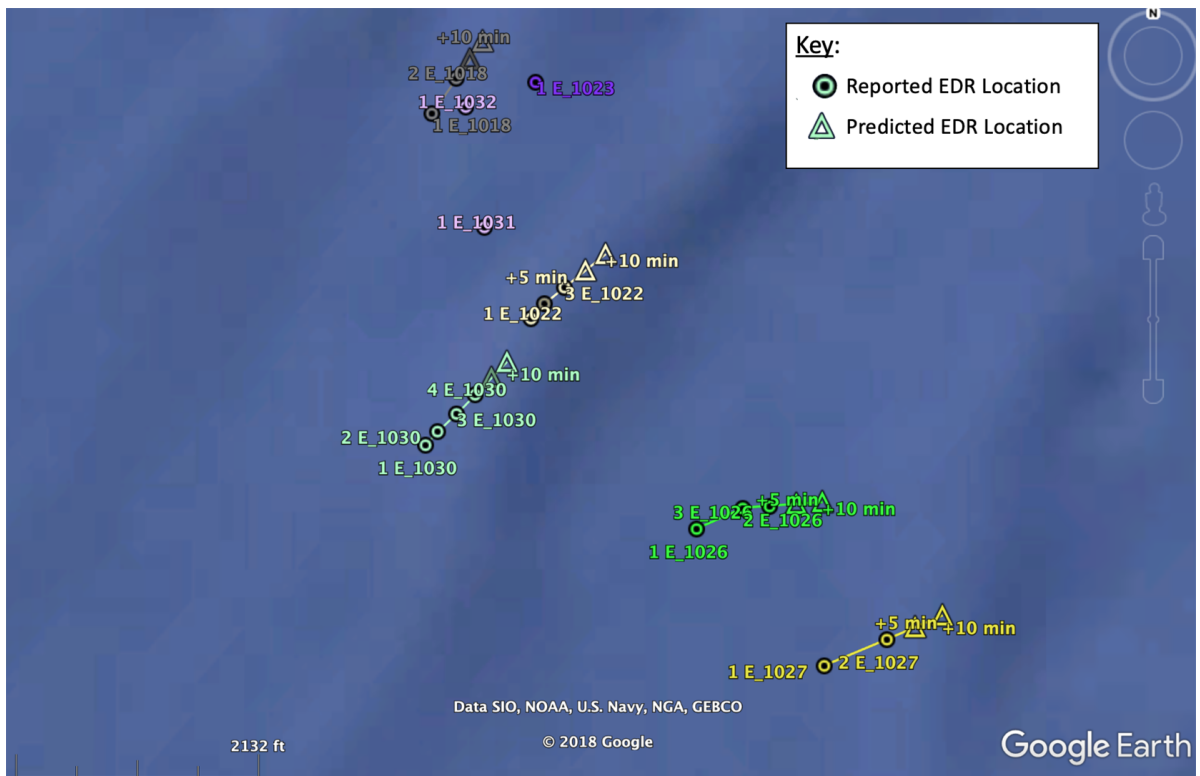
Local Date & Time: 00:29:55 2019-11-12
 UTC Date & Time: 05:29:55 2019-11-12

EDR ID	EDR Time	Age (min.)	Latitude	Longitude	Volt.	Date	IMEI ID	Heading	Speed (kts)
E_1015	17:58:00	403891.9	29.555528	-95.090240	12.05	2019-02-04	3700	N/A	N/A
E_1018	11:35:00	191154.9	28.4562	-80.480041	11.7	2019-07-02	5630	35	0.4
E_1019	17:52:00	403897.9	29.55493	-95.089736	11.98	2019-02-04	7560	N/A	N/A
E_1022	11:29:00	191160.9	28.451112	-80.477048	12.12	2019-07-02	8700	51	0.4
E_1023	11:43:00	191146.9	28.456104	-80.477848	11.98	2019-07-02	9740	N/A	N/A
E_1026	12:02:00	191127.9	28.44582	-80.471409	11.98	2019-07-02	7780	86	0.5
E_1027	11:56:00	191133.9	28.442616	-80.468201	12.12	2019-07-02	6630	67	0.5
E_1028	21:05:00	382104.9	29.55419	-95.090496	12.19	2019-02-19	0200	N/A	N/A
E_1029	17:17:00	382332.9	29.554414	-95.090041	12.26	2019-02-19	7230	N/A	N/A
E_1030	11:18:00	191171.9	28.448052	-80.480016	12.26	2019-07-02	9210	47	0.4
E_1031	11:36:00	191153.9	28.452572	-80.479255	12.26	2019-07-02	3150	N/A	N/A
E_1032	11:42:00	191147.9	28.4555	-80.479777	12.19	2019-07-02	5150	N/A	N/A

- Organized by EDR number

- Color coding of critical data ("Age" & "Battery voltage status")

Google Earth Display:



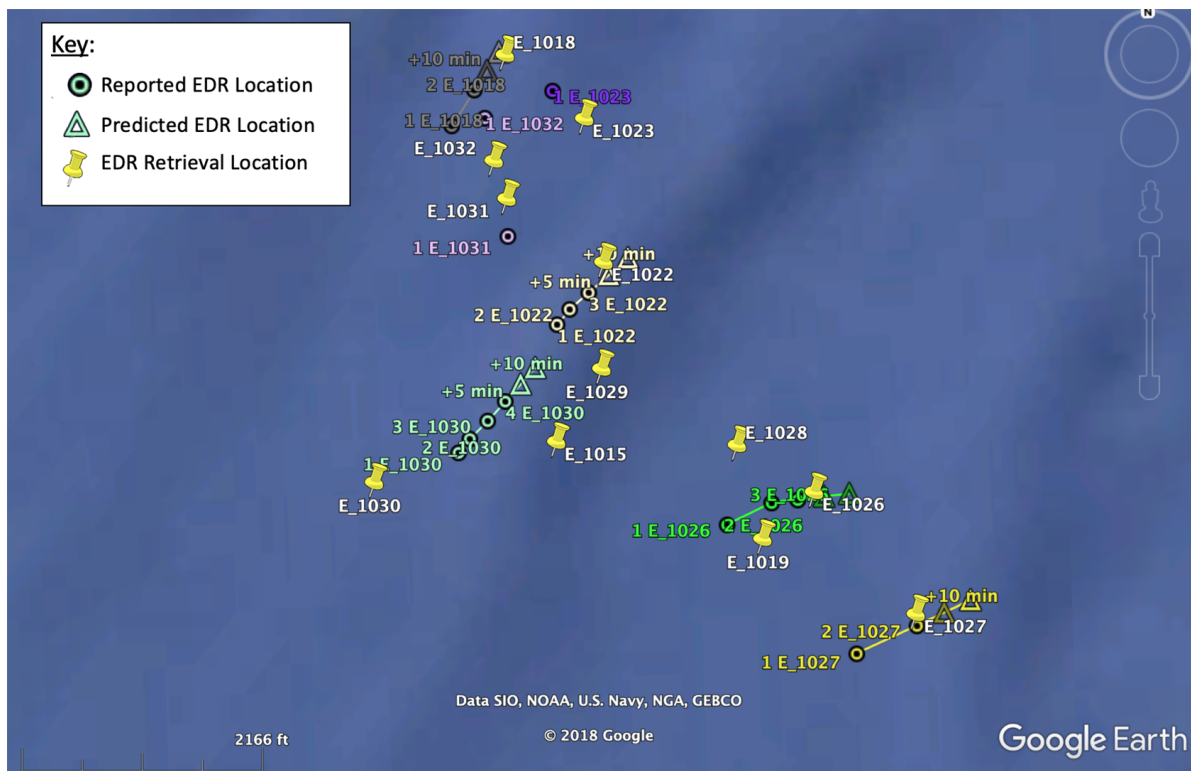
Google Earth Display - Examples of Location Predictions:



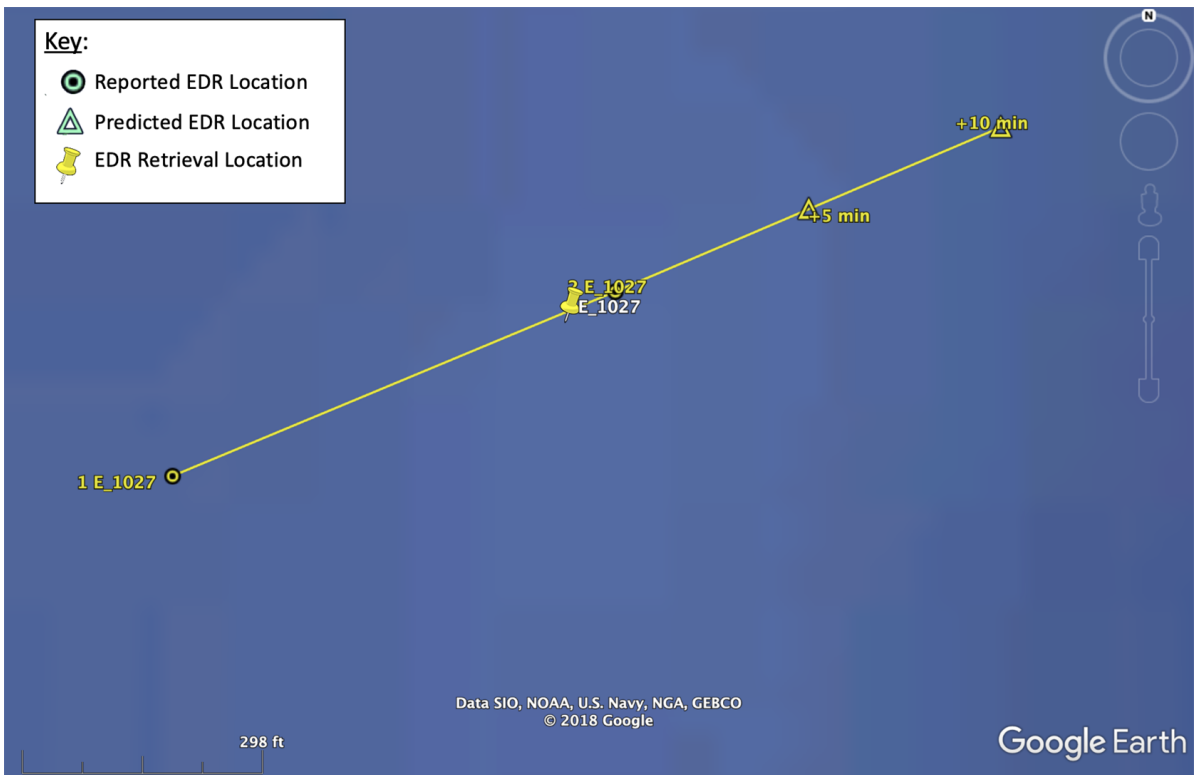
RESULTS SUMMARY

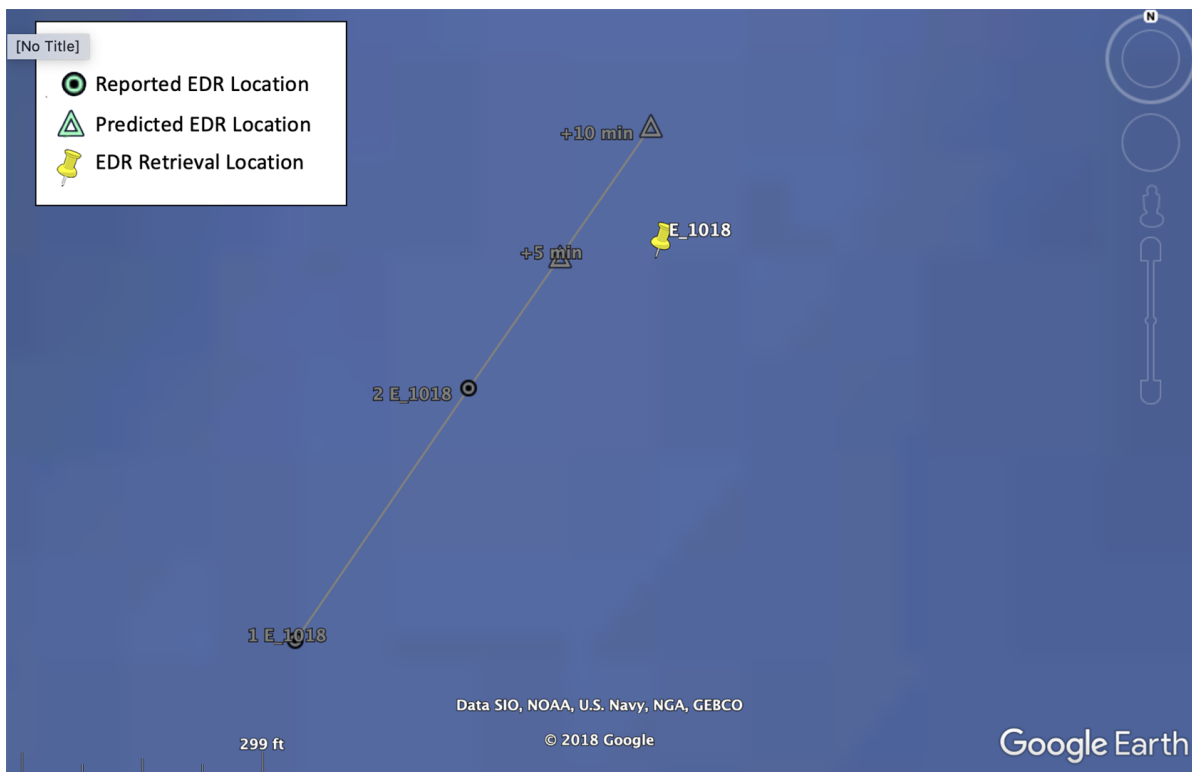
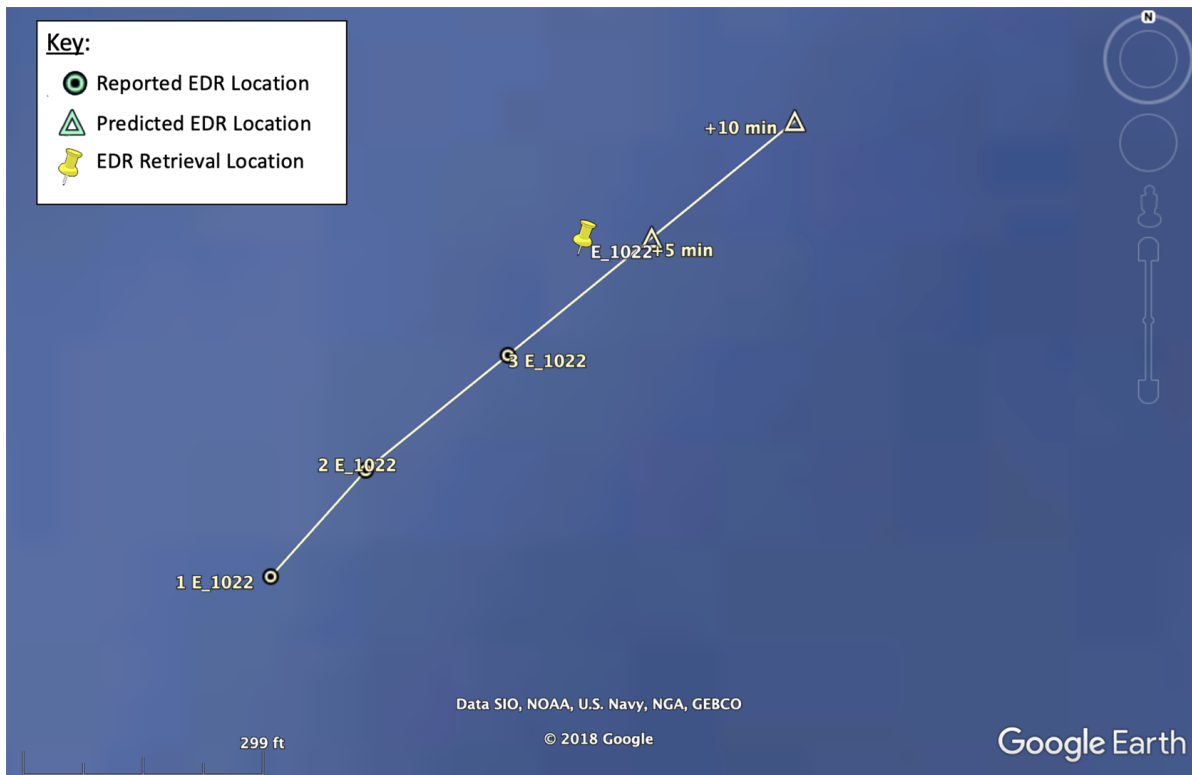
Overall Results:

- Total of 12 EDRs ejected
- 12 EDRs transmitted data:
 - Only 8 EDRs transmitted valid data prior to being found & recovered
 - 5 EDRs transmitted enough data points to generate valid tracklines & location prediction estimates
 - 4 EDRs did not transmit valid data prior to being retrieved
- All EDRs were retrieved within 52 minutes from ejection



Prediction Tool Results:

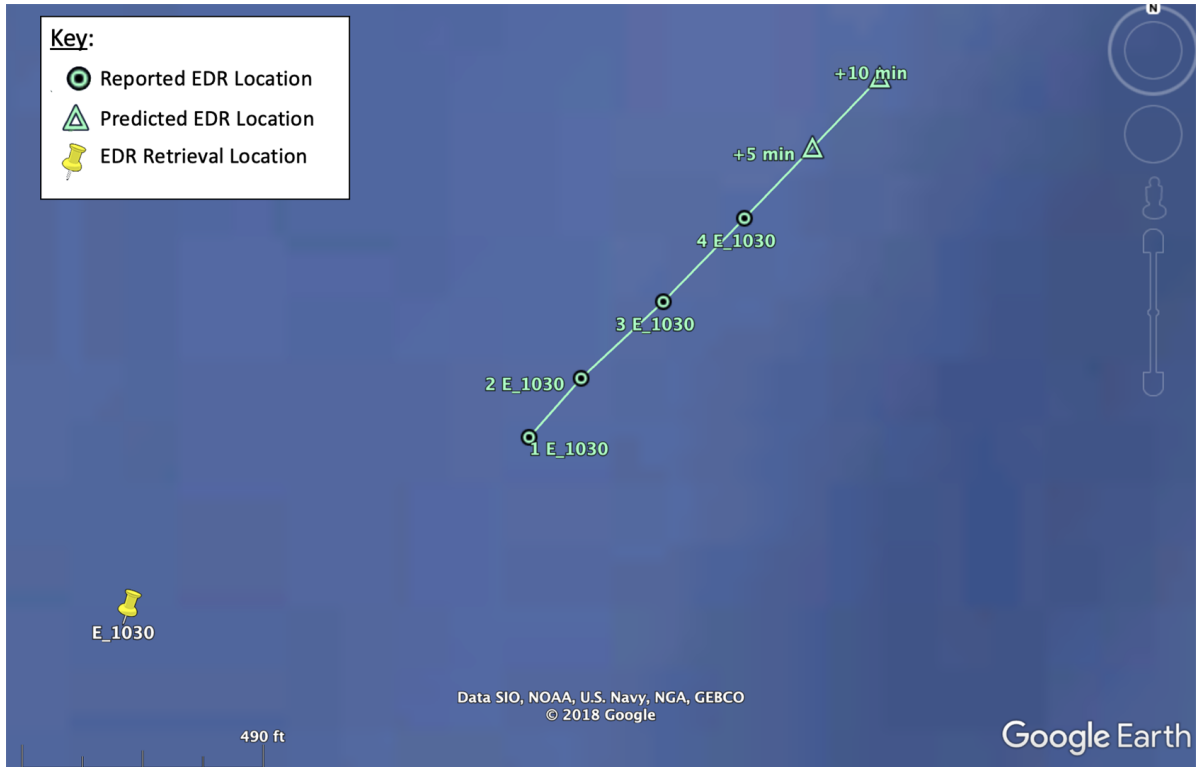




- Measured distances between Actual vs. Predicted locations was <38 meters (124 ft)

Some Unexpected Results:

- In 3 instances, reported locations and retrieval locations did not match up as expected
- Possible factors:
 - Individual GPS location accuracy offset
 - Elapsed drift time between last reported and recovery location
 - Potential error in retrieval coordinate logging



CONCLUSIONS

- Translation of binary data into Google Earth (GE) mapping tool allowed for rapid & seamless spatial arrangement of vital information
- The use of GE allowed for depicting drift patterns, which aided recovery vessel operations
- Prediction tool provided an additional resource for locating EDRs
- Software can be customized for supporting multiple Iridium (or similar) applications that require real-time information and situational awareness
- Depicting large amounts of data in real-time is very complex, requiring ample customizations & challenges to balancing tool requirements



ABSTRACT

On 2 July 2019, the NASA Ascent Abort 2 flight took place off the Florida coast to test the emergency systems to separate the Orion Crew Module (CM) from the future Space Launch System rocket in the event of a malfunction. During this high-altitude test, instrumentation data was recorded on twelve customized buoyant Ejectable Data Recorders (EDRs) and subsequently jettisoned from the CM in mid-air. Upon release, the EDRs activated their GPS-Iridium beacon systems and began transmitting Short Burst Data (SBD) messages via the Iridium satellite network to relay their individual location and system health information. To locate, track and retrieve each EDR from the ocean surface in real-time, multiple open-source programming tools (Python and Linux shells) were developed for parsing the incoming Iridium binary SBD messages. For this, a Linux laptop was used to receive the Iridium-generated emails containing the SBD messages and autonomously execute the parsing tools. The received SBD data contained location, timestamp and health status information that was translated, saved, and subsequently used for simultaneously generating a continuously updated color-coded tabular display summary and unique KML files used with Google Earth to track their locations. Once their locations were known, dedicated recovery vessels retrieved all EDRs from the ocean. An additional tool was also developed in order to generate 5- and 10-minute geolocation predictions for each EDR by deriving the displacement distance, elapsed time, displacement heading and velocity based on the latest known information available. The recovery vessels were also tracked with the use of a separate commercial GPS beacon system. After jettison, 67% of the EDRs transmitted valid data by the time they were retrieved from the ocean. However, the real-time information presented by the plotting tool allowed for the ready depiction of EDR dispersal patterns and reference drift trajectories, which contributed to the recovery of all twelve EDRs and the AA-2 flight data. Lastly, the available data showed that the distance between the software's reported drift/predicted locations and the recovery locations did not exceed 38 meters, therefore demonstrating the advantages of this software tool for supporting real-time tracking and recovery efforts of beacon devices.

SWITCH TEMPLATE

