Harlem Launch Alliance Inc.

Messenger-3 Mission Pre-Flight Report

Team 1 Project Technical Report for the 2018 IREC

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The CX-4 Dwayne "The Rocket" Johnson is the third rocket manufactured by Grove School of Engineering's student-run Harlem Launch Alliance Inc. IREC 2018 is the HLA's third attendance at IREC, and like it's first and second, the general goal of Project Messenger is the demonstration of an attitude-triggered compress-gas initiated dual-event deployment recovery system. The Messenger-3 mission is entered into IREC's 10K-COTS all propulsion types category with a target altitude of 10,000 feet AGL. The CX-4 is a 102 inch long, 6.2 inch wide single stage, single motor high-power rocket with a maximum ceiling of just over 13,738 feet. The CX-4 is intended as refinement of the composites manufacturing lessons learned during our first participation at IREC, and of the recovery system electronics lessons learned at our second. We look forward to learning even more at IREC 2018.

I. Introduction

Harlem Launch Alliance Inc. of the Grove School of Engineering at the City College of New York-CUNY set off on Project Messenger in January of 2016. The goal was to develop the necessary design, analytic, manufacturing, and management skills to create a first-rate amateur aerospace program at arguably the best publically-funded engineering school in the country. Beyond bringing pride to the college, we hoped to bring amateur aerospace engineering to our New York City neighborhood of Harlem, which has no history in this sort of pursuit, as well as to the east coast which has a very small number of amateur rocketry programs at all.

City College has been summed up as an Ivy League education without the grade inflation. Indeed, students at CCNY express pride at overcoming the unique set of challenges presented at an underfunded, under-resourced, oftentimes corrupt and incompetent college in the middle and very much apart of our Harlem community. Because of these uniquely challenging circumstances, everything done on campus that is worthwhile is done exclusively by students, for students. The aerospace program is no exception.

The HLA became fully independent of CCNY administration this past December when it secured its 501(c)3 status as a federally tax exempt non-profit. The Spring semester was spent not just learning how to build rockets, but how to build an organization. It was an at times painful learning process, of course compounded by the inherent

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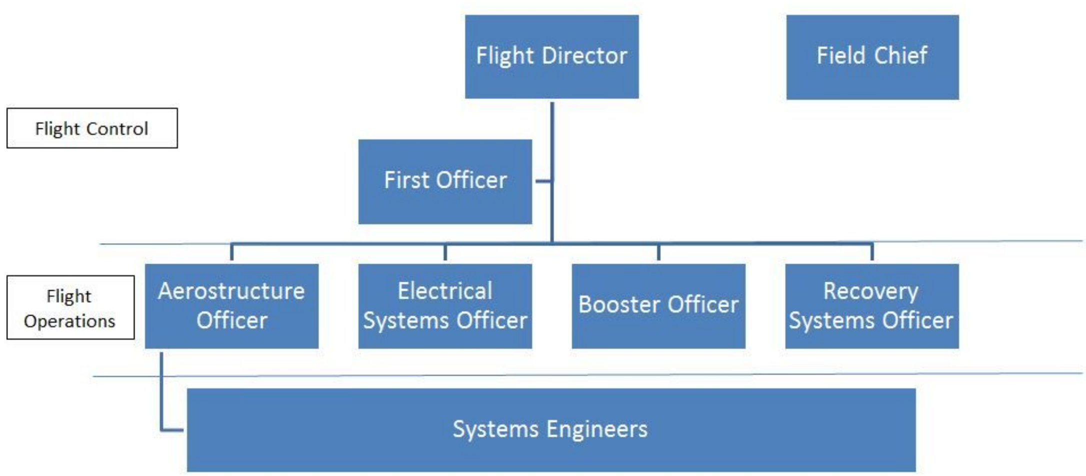
challenges present in any collegiate rocketry program.

The Messenger-3 mission was designed to demonstrate a refined appreciation for the hard lessons learned at IREC 2016 and 2017. Technically speaking, that meant a return to fully manufacturing the airframe after a year hiatus after IREC 2016 and more attention to detail paid to the attitude-triggered recovery system. Organizationally, that required a more professional engineering management structure to coordinate the four working groups (airframe, booster, electronics and recovery systems). This was no small task as these groups numbered anywhere from 3-12 people, rivalling individually the size of the entire Project of only a year ago! Administratively, Messenger-3 required planning, budgeting, ordering, recruiting, training and coordination on a scale no student-run project out of the GSOE ever had the need to display. It is with a sense of frustration that we report we were only partially successful in our first four months as a completely student-run organization in executing these requirements. It is with a sense resolve that despite these administrative, managerial and technical setbacks, we are resolute in seeing the CX-4 on the pad at IREC 2018.

Messenger-3 Flight Operations are organized exactly as they were last year. A Flight Director together with a First Officer make up Flight Control and are responsible for managing the Flight Team. The Flight Team is made up of four Flight Operations Officers, one for each major subsystems of the rocket: Electrical, Recovery, Aerostructure and Booster. Each Operations Officer has a team of 1-3 Systems Engineers. This year, we're including the addition of a Field Chief who is manages the Field Team, responsible for, among other things, the setting up of the basecamp, coordinating the movement of material and personnel and for recovery operations. To be compatible with the *Spaceport America Cup Range Standard Operating Procedures*, the following table shows the equivalent Messenger-3 Flight/Field Team positions with the Student Team Leadership roles:

Messenger-3 Roles	**Equivalent SAC Student Team Leadership**
Flight Director	Project Manager, Launch Operations Lead
First Officer	Deputy Project Manager
Field Chief	Recovery/Safety Operations Lead



II. System Architecture Overview

The CX-4 is a single stage, single engine high-power rocket intended to test attitude-triggered CO2 cartridge deployment systems. The main design consideration in the Odyssey's layout was the use of the Aerotech M795.

Propulsion Subsystem

As the CX-series rockets are intended as a test bed for recovery systems and airframe manufacturing, Project Messenger has usually exercised caution with motor selection and has traditionally chosen the Aerotech M750. The M750, usually used as a second stage motor, is generally considered to be reliable and has a gentle thrust curve. Due to supply issues with AMW Pro-X, the vendor for SAC, the M750 is not available. Instead, the CX-4 will fly on a Cesaroni M795. The two motors are compared below.

AeroTech M750

Manufacturer:	AeroTech
Entered:	Jul 5, 2007
Last Updated:	Jul 22, 2014
Mfr. Designation:	M750W
Common Name:	M750
Motor Type:	reload
Delays:	P
Diameter:	98.0mm
Length:	73.2cm
Total Weight:	8776g
Prop. Weight:	5540g
Cert. Org.:	National Association of Rocketry
Cert. Date:	Jun 16, 2007
Average Thrust:	744.0N
Maximum Thrust:	1454.0N
Total impulse:	9325.0Ns
Burn Time:	12.7s
Case Info:	RMS-98/10240
Propellant Info:	White Lightning
Availability:	regular

Cesaroni M795

Manufacturer:	Cesaroni Technology
Entered:	Feb 19, 2008
Last Updated:	Jun 26, 2014
Mfr. Designation:	10133M795-P
Common Name:	M795
Motor Type:	reload
Diameter:	98.0mm
Length:	70.2cm
Total Weight:	8492g
Prop. Weight:	4892g
Cert. Org.:	Canadian Association of Rocketry
Cert. Designation:	M795-P
Cert. Date:	Oct 30, 2004
Cert. End:	Jan 31, 2010
Average Thrust:	794.0N
Maximum Thrust:	794.0N
Total impulse:	10133.0Ns
Burn Time:	12.8s
Isp:	211s
Case Info:	Pro98-4G
Propellant Info:	Classic
Availability:	regular

The M795 has a higher total impulse and average thrust, while having a lower maximum thrust and burntime. The lower maximum thrust is desirable as it reduces the peak compressional loading on our SRAD airframe. OpenRocket simulations show the M795 taking the CX-4 to a ceiling of over 13,000 feet.

Aero-structures Subsystem

Electronics Subsystems

The Electronics team at the Harlem Launch Alliance has, after months of design and engineering, been successful in manufacturing a reliable and sophisticated flight computer. The aforementioned – a roughly 4” x 4” circuit board has all the capabilities deemed necessary for consideration into the ATR challenge: a gyroscope (measuring angle) dependent drogue release logic, and a barometric altimeter main chute release logic. Team 1’s flight computer uses printed circuit board(PCB) technology to cleverly coalesce sensors, microprocessors, RF communication, and highly efficient software. Thus, not only does the fully-functional SRAD flight computer rival many of its COTS counterparts, it surpasses them as it includes wireless data transmission capabilities.

Hardware Details

Table. 1 lists the components of the Messenger-3 flight computer *that qualify it for consideration into the ATR challenge pool.*The team has made every effort to keep the design *cost efficient* without compromising efficiency. The prices for some components, such as the AmazonBasics 9-V Battery and the 9V Battery Holder with Switch are obtained by dividing price of a pack of component by the number of components in it.

Component Integration

Powered by a D-type 9 volt battery, the Arduino Pro Micro access data from the \ GY-521 and MPL3115. These have the ability to provide raw/pitch/yaw and height AGL (in meters) respectively. Periodically, the Pro Micro reads raw unfiltered attitude and altitude related data using a I^2C protocol. Additionally, the Pro Micro converts the raw data into filtered data that is easy to analysis, in a .csv format to an 8 gigabyte micro-SD card using the serial peripheral interface (SPI). Indirect control over the micro-SD card is provided by the Adafruit-manufactured MicroSD Card Breakout Board, which grants it access to its memory. Once sensor data is determined to fulfill programmed chute-release logic, the Pro Micro sends a digital "HIGH" signal to a relay switch, which then releases a high current, triggering chute deployment. This procedure is done in two different cases – one when the state variables fulfill the drogue chute release logic, and the other when the state variables fulfill the main chute release logic.

Power Considerations

In layman terms, *all*components integrated into the PCB powered by 5V battery. A schematic of the PCB and wiring are shown in the appendix. A 9V battery source is used, which feeds into a 5V voltage regulator, Arduino Pro Micro. All other major external boards and sensors are powered by the Arduino's V_{CC}(voltage common collector, or its operating voltage), which is set at 5V. All non-Arduino components integrated into the PCB: the GY-521, MPL3115A2, and the microSD Card Breakout Board+ operate at a regulated ~3V range (as such, each component has its own, embedded regulator). The relay switch has an external power source of 9V and accepts digital logic (to trigger the switch) in the form of 0V and 5V (which is provided by the programmable pins on the Arduino). The battery holder switch acts as a physical arming mechanism. None of the aforementioned components will run without it being on the

At a given deployment angle, the primary circuit will send out a signal to activate the e-matches for the RAPTOR CO2 Ejection System, deploying the drogue chute. There is a feedback loop connecting the primary GY-89 and its computer to the secondary GY-86 system which will ignite the e-matches if the first system fails to trigger the relays. A second feedback loop connects the output of the relay to the backup system in case the primary system triggers the command but the relays do not activate. Since the backup is operating independently from the primary circuit, activating separate relays, it will not be affected if the first system fails. At the targeted altitude, the primary system will trigger the e-matches and deploy the main chute. The same feedback system is used to verify the deployment of the main chute.

Recovery Subsystems

Overview

The principle component of the recovery subsystem is the two RAPTOR CO_2 Ejection Systems, manufactured by Tinder Rocketry. The RAPTORs can discharge CO_2 cartridges ranging from 20-85 grams. The CX-3E flies with two 35g cartridges. The RAPTORs blow off the nose cone and deploy the drogue parachute. The main parachute is deployed after the firing of a recovery tether (Tinder Rocketry) that severs the link between the drogue chute and the rocket airframe. The drogue then pulls out the main parachute bag.

Drogue Parachute Deployment

The RAPTOR CO_2 Ejection System consists of a charge cup loaded with 3F gunpowder that, when ignited, pushes a puncture pin against a return spring and into the top of the CO_2 cartridge, puncturing it. The CO_2 then escapes quickly out of four holes in the side of the mounting cap. The major components are shown schematically below.

There are three different charge cups for two different e-match types: two J-tek-type (single and dual) and the no-longer manufactured Q2G2 igniters. For redundancy, we'll be using the dual J-tek e-match charge cup.

The J-tek e-matches employed on the CX-3E are manufactured using CF-24 e-match compound. Between two RAPTORs, that's four J-tek e-matches (two per RAPTOR). The RAPTOR can be used with CO_2 cartridge sizes ranging from 20-85 grams. We will use the 35 gram cartridges (the largest ones that came with the RAPTOR kit).

Main Parachute Deployment

The drogue chute is tied off both to the top of the main parachute bag and to the rocket airframe. The line that connects the drogue to the airframe is split by a recovery tether (Tinder Rocketry). The recovery tether also uses MagFire MF-24 e-matches. The main charge consists of 0.25 grams of 4F gunpowder. The recovery tether on the rocket will be configured with two MF e-matches for redundancy.

Parachutes

Both the main and drogue parachutes are pre-manufactured by Fruity Chutes Inc. The drogue chute is a 36 inch Iris Ultra rated at 7 lbs @ 20 fps with a drogue coefficient of drag is 2.20. The main parachute is 72 inch Iris Ultra rated at 28 lbs @ 20fps also having a coefficient of drag of 2.20.

Review

The RAPTOR CO_2 Ejection System has advantages towards other COTS ejection systems for many reasons. First, it is a compressed gas ejection system that poses no threat to the parachutes that will be placed inside the chamber. Many high-power rockets use pyrogen to separate and deploy the parachutes. The presence of pyrogen in the rockets is hazardous during transportation and put the lives of ground personnel on risk if not deployed. The RAPTOR CO_2 Ejection System uses compressed CO_2 gas to deliver a safe and instantaneous deployment. Second, there are many different sizes of CO_2 cartridges varying from 20-85g that can be installed. Third, it only uses the explosion of a small amount of pyrogen which is also contained inside the RAPTOR CO_2 ejection system housing to release the CO_2gas and the housings are reusable. Fourth, the RAPTOR CO_2 Ejection System kit comes in three different charge cups to satisfy various demands and is easy to assemble. Our team had tested and used the same RAPTOR CO_2 ejection system last year and its proven a reliable deployment system.

III. Mission Concept of Operations Overview

Notable Software Details

The flight computer functionality is programmed using Arduino code, which is compatible with the Pro Micro 5V/15 MHz microcontroller. The primary state variables that will be used to determine the fulfillment of drogue and main chute release logic are as follows: $\boldsymbol{H_{main}, \Theta_y, \Theta_p}$.

Software Architecture

While crucial header files (for instance, wire.h, SPI.h, and SD.h) are included in the global scope, along with important constants, such as $\boldsymbol{H_{main}}$, the majority of the code is written within the Arduino loop. In simple terms, most of the code – such as reading sensor values, and writing to microSD memory - is written with the intent of it being executed repetitively. Certain functions, such as the parsing of sensor values (from raw, unfiltered values to human-readable data - $\boldsymbol{\Theta_y}$ ***and*** $\boldsymbol{\Theta_p}$) is done within user-defined functions outside of the setup and loop functions, they are all called within the scope of the primary Arduino loop.Large blocks of code are written under if statements with the intent of discriminating between the different *modes* that the flight computer runs under (discussed further in *Concept of Operations*).

Important Data Structures and Procedures

An array with a capacity of 5 will be used at all times for storing gyrometer values. This is done with the intent of reducing noise in gyrometer readings. For example, 5 gyrometer readings, obtained at times $\mathbf{t_0}$**,** $\mathbf{t_1}$, $\mathbf{t_2}$, $\mathbf{t_3}$, $\mathbf{t_4}$, will be stored in the 1st, 2nd, 3rd, 4th, and 5th memory slots respectively. As such, the latest value for gyrometer readings will always be stored in the 5th memory slot, and the array will follow a FIFO (first in first out) method of storing data. In order to determine whether $\boldsymbol{\Theta_y}$ ***or*** $\boldsymbol{\Theta_p}$ have achieved their critical values, the average of the previous 5 readings (inclusive of the latest one) will be averaged and then compared. If this requirement is met, the code will then verify that each successive gyrometer reading in the array reflected a value closer to the horizontal.

SD Card data will also be stored in an array (including important variable data, such as altitude, pitch and yaw), which will then be stringified in a manner compatible with .csv Microsoft Excel compatible file formats.

Concept of Operations

The Messenger-3 Flight computer has two distinct “modes”: unarmed and armed. When the flight computer is first turned on it is set by default to unarmed mode. It stays in this mode until the flight computer detects a height of 3500 ft AGL, switching to *armed*mode. Note that regardless of modes, data is acquired and stored in a microSD card (storage of data is not mode-dependent). The *armed* mode can be divided further into two modes: *ascent and descent,* as seen in Fig. 1.

1) *Unarmed* – In this state, no voltage can be provided to the relay. Indirectly, this means that the pins 8 and 9 (digital pins for drogue and main chute relays) will be kept in a non-triggering state. (HIGH for Active LOW relays and LOW for Active HIGH relays). The microcontroller with the help of the sensors, will continually be looking for a height of 3500 AGL to transition to the *Armed* mode

2) *Armed* (Altitude of 3500 AGL has been reached). This state can be further divided into two different sub-modes:

a. *Ascent* – While in armed ascent, the rocket is gaining altitude, and hence is not under the influence of any of the two parachutes, none of the parachutes have yet been released. The release of the drogue chute is dependent upon the angle of the rocket from the horizontal, in **two** different axis. If the pitch **or** the yaw values for the rocket are 30º from the horizontal, the drogue chute relay will release a high current output.

b. *Descent* – While in armed descent, the rocket is **losing** altitude, and is under the influence of the drogue chute. The transition from armend ascent mode to descent mode is contingent upon a Boolean variable reflecting the status of drogue chute release. The flight computer will compare altimeter reading with H_{main}. If a height within a 10% percent range is found, or if the height is less than H_{main}, the main chute relay will release a high current output

Testing was an enjoyable experience for the team. The majority of this done with the focus on **subsystems**, i.e. the testing of each component individually. In general, these tests were successful. For instance, data was extracted from the GY-521 (raw/pitch/yaw) and verify the values using basic equipment such as protractors. Altimeter data was also tested on an individual level and was verified by increasing/decrease altitude of tests. A final integrated test remains to be conducted besides tests on the complete flight computer.

Throughout this experience, the team learned – in simple terms – a lot. A couple of the team members working on the electronics had the opportunity to work with IMUs and GPS modules for the very first time. In addition to this, this was the first time any of the members had ever ordered a custom-made PCB, let along designed one. By the end of the project, a majority of the team was more than well-versed in the technicalities surrounding Arduinos, including the inherent properties of electric circuits that all CPE/EE majors must live by. In the future, we wish to reduce the overall size of the Flight Computer, as it's still much bigger than its COTS counterpart – The Raven3. We aim to do this by improving the quality of our PCB design and/or purchasing multipurpose IMU's and sensors.

IV. Conclusions and Lessons Learned

As with almost every major engineering project, there were moments where certain things simply did not work. In short, there were problems - a lot them, in fact. However, these were all received as opportunities to learn more about the art of electronics manufacturing and proper time management. For example, many meetings were indecisive. It was often the case that the conflicting ideas (regarding payloads, for example) among the many (at one time, over 10) team members became superfluous. In some cases, this even became counterproductive. However, as more structure was given to the team (a separate Payload division) the burden of picking one option out of many was considerably reduced. In certain cases, the team suffered disadvantages caused by technical inexperience. For instance, the initial PCB that the team designed and had manufactured, was not able to integrate the GPS module. To fix this problem, the team had no other option to look through the design again and make the proper adjustments.

System Weights, Measures and Performance Data Appendix

SEE FINAL PROGRESS REPORT

Recovery Test Reports Appendix

<u>Recovery System Testing</u>

Main Parachute Recovery Tether Test:

After drogue chute deployment two lines run from the drogue chute: one line runs from the drogue chute to the rocket airframe, while the second line runs from the drogue chute to the main parachute bag. The line that connects the drogue chute to the main chute bag is slack while the line that runs from the drogue chute to the rocket airframe is under tension. There is a recovery tether (quick-release) that breaks the drogue chute - rocket airframe line in half. When the rocket falls through a certain altitude under the drogue, the recovery tether engages, severing the connection between the drogue chute and the airframe and allowing the drogue chute to pull the main parachute bag out of the rocket.

The recovery tether is made of heat-treated, copper-toned, anodized aluminum, is rated for rockets up to 60lbs and can sustain shock loads of up to 2000lbs.

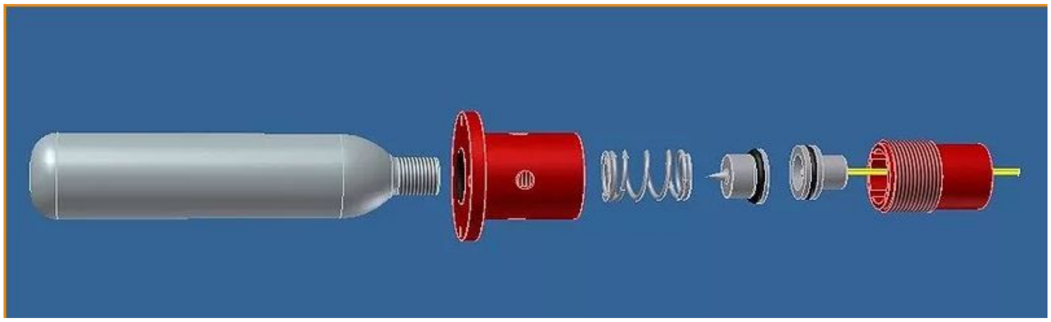
The the recovery tether was tested by hanging 35 lbs (the approximate burnout weight of the CX-3E) from a cross-beam with the quick-link in the middle.

Test of the quick-link before, during and after.

The initiator was an MF-24 Rocketflite 26 gauge solid copper wire e-match. The main charge consisted of 0.25 grams of 4F black powder and the battery used supplied 12V at 200 mAh (the all-fire rating for the e-matches is 1.6 amps @ 1.5 V DC).

CO2 Cartridge Ejection System Test:

The main element of the CX-3E's recovery system is Tinder Rocketry's RAPTOR CO2 Ejection System. There are two RAPTOR's onboard, and can use any CO2 cartridge from 20 - 85 grams.



Model of the RAPTOR CO2 Ejection System.

In flight, the CX-3E will fly with 35 gram cartridges. For the test, however, we will be using the smaller 23 gram cartridges. The test consists of two separate firings: the first firing will be with the parachute compartment *empty.* This will be a test of the RAPTOR itself, and is not expected to blow the nose off of the airframe. The second firing consists of packing the parachute compartment with the main and drogue chutes and again using a 23 gram cartridge. With much less volume available for the expansion of CO2, this second test is to determine if the RAPTOR is sufficient to separate the nose from the airframe. If a 23 gram cartridge is satisfactory for this purpose, then the 35 gram cartridges used in flight will be more than sufficient.

By the time of writing, the RAPTOR test had not been completed. The test is scheduled for May 30th.

External vs. Internal Power:

The tests mentioned above used supplied voltage and current well in excess of the e-match All Fire ratings. The e-match leads were simply touched to leads of large 12V batteries to initiate the black powder charges. These tests will be repeated using the CX-3E's actual electrical system in early June. The logic of performing the test in this way is that the power supplied directly from the battery (external power) will certainly provide enough electrical power to initiate the charges. The external power tests are thus tests of the only the recovery hardware itself. Tests using the rockets actual electrical power supply (internal power) is a dual test of the hardware and of the CX-3E's electrical systems.

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Hazard Analysis Appendix

The principal hazards associated with the CX-3E's flight in IREC 2017 is the transportation of chemical and compressed gas energetics.

Chemical Energetics

Chemical energetics include the four fuel grains for the M750W solid motor, the pyrogen for the MF e-matches (for the recovery tether), pyrogen for the J-tek e-matches (for the RAPTOR CO2 Ejection System), 4F gunpowder (for the recovery tether) and 3F gunpowder (for the RAPTOR).

Compressed Gas Energetics

Compress gas energetics include 23 gram and 35 gram CO2 cartridges needed for the RAPTOR CO2 Ejection System.

Chemical Energetics Mitigation Approaches

Mitigation approaches for the chemical pyrogens consist of two main approaches:

1) Physical separation of the different pyrogens.

2) Maintaining a storage temperature below 140 degrees fahrenheit (the lowest safety-critical temperature of the above listed pyrogens) and insulating the containers from static electricity discharges.

On the first point, there will be separate plastic containers for the M750W fuel grains, the e-match pyrogens and the 3F/4F gunpowder. On the second point, the pyrogens will be transported to New Mexico in a climate controlled RV, stored inside a climate controlled room while awaiting transportation to the Spaceport, and finally transported and temporarily stored again in the RV at the launch range. To avoid static electricity, containers in immediate contact with pyrogens will be either plastic or glass. Additionally, pyrogen containers will be transported in plastic tool boxes.

Hazard Analysis Appendix
The principal hazards associated with the CX-4's flight in IREC 2018 is the transportation of chemical and compressed gas energetics.

Chemical Energetics
Chemical energetics include the pyrogen for the MF e-matches (for the recovery tether), pyrogen for the J-tek e-matches (for the RAPTOR CO_2 Ejection System), 4F gunpowder (for the recovery tether) and 3F gunpowder (for the RAPTOR).

Compressed Gas Energetics Compress gas energetics include 23 gram and 35 gram CO2 cartridges needed for the RAPTOR CO_2 Ejection System.

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Risk Assessment Appendix

Team 01	**Project Messenger**	**5/25/18**		

Hazard	Possible Causes	Risk of Mishap and Rationale	Mitigation Approach	Rick of Injury
Explosion of solid-propellant during launch with blast or flying debris causing injury	Cracks in propellant grain Debonding of propellant from wall Chunk of propellant breaking off and plugging nozzle Motor casing unable to contain normal operating pressure Motor end closures fail to hold	Medium; pre-manufactured engine, assembled by students, inherent risk present in solid motor operation	Visual inspection of propellant sections before assembly Inspection of engine after assembly for cracks, gaps or debonded sections Inspection of fuel grain after assembly Inspection of motor casing for any obvious defects Inspection of assembled engine by group of not involved with initial assembly	Medium-Low
Rocket deviates from flight comes contact personnel at high speed nominal path, in with personnel at high speed	Structural failure	Medium-Low, main fin and mid-body fin sets are secured with epoxy-shredded fiberglass	Medium-Low, main fin and mid-body fin sets are secured with epoxy-shredded fiberglass	Low

Recovery system fails to deploy drogue chute, rocket comes in contact with personnel	CO_2 cartridge failure Drogue chute becomes tangled after deployment E-match leads break under flight stresses	Medium-low, pre-fabricated RAPTOR CO_2 Ejection System, student-manufactured e-matches	Keep out of heat before installation into rocket Deploy drogue at a larger angle of attack to avoid tangling with the booster Load each RAPTOR with two e-match leads per BP charge	Low Low Low
Recovery system partially deploys, rocket or payload comes in contact personnel	Drogue gets tangled with booster Main chute deployment fails, or partially fails	Medium, no in-flight recovery system tests	Deploy at larger angle of attack Electrical system redundancy and ensure there are no sharp edges for the main chute bag to get caught on	Medium-low

Recovery system deploys during assembly or prelaunch, causing injury	Gyroscope orders deployment while rocket is held sideways	Low, recovery system requires an altitude of 3500 feet in addition to the angle requirement for deployment	Keep electronics in a “sleep” mode until rocket is on the rail	Low
Main chute deploys at or near apogee, rocket or payload drifts to highway	Recovery is tether is triggered prematurely	-Medium, escaping CO_2 during drogue chute deployment may push main parachute bag out of the airframe prematurely.	Install pressure-relief tubing that allows escaping CO_2 to vent around main parachute bag	Low

Assembly, Preflight, and Launch Checklists Appendix

<u>Off-Range Tasks</u>

Procedures to be carried out before the rocket is brought to the range

- Motor assembly and integration (refer to M750W assembly instructions)

- Packing the Main Parachute

- Rigging the Recovery System (without the CO2 cartridges)

<u>Needed Supplies</u>

❏ TWO (2) 23 gram CO2 cartridges

❏ Ryobi drill with phillips head

❏ Igniter

- ❏ Alligator clips
- ❏ Side Panel
- ❏ TEN (10) 8-32 bolts
- ❏ Nosecone
- ❏ Super Lube

Range Procedures

Procedures to be carried out after rocket passes safety inspection and is brought out to the range to be launched

- ❏ Anim carries the igniters and alligator clips onto to the range
- ❏ Sid carries TWO (2) 23 gram CO2 Cartridges, side panel, and Ryobi drill onto to the range
- ❏ Hadia, Jaret and Tamar carry the rocket onto the range (MAKE SURE THE NOSE IS ON)
- ❏ With the assistance of IREC range authorities, Hadia, Jaret and Tamar load the rocket onto the rail
- ❏ Anim gives the igniters to the IREC range authority
- ❏ Sid lubes RAPTOR O-rings with Super Lube
- ❏ Sid installs the TWO (2) 23 gram CO2 Cartridge into the RAPTOR CO2 Ejection System
- ❏ Tamar activates the electronics
- ❏ Tamar places and HOLDS panel onto rocket
- ❏ Sid screws the TEN (10) 8-32 bolts into the panel
- ❏ Range is evacuated

IF MOTOR DOES NOT START, DO THE FOLLOWING

- ❏ Wait 10 seconds
- ❏ Commence a new countdown
- ❏ If a total of FOUR (4) attempts fail to start the motor, wait for clearance from range safety officer
- ❏ Once clearance is given, Sid, Tamar, Anim, Hadia and Jaret approach the rocket with the Ryobi drill, a new igniter, and alligator clips.
- ❏ Sid removes panel
- ❏ Tamar turns electronics OFF

- ❑ Anim removes alligator clips

- ❑ Anim removes igniter

- ❑ Tamar TURNS ON ELECTRONICS
  *Electronics are turned on before connecting igniter with alligator clips in case a static charge fires the igniter and the rocket goes off.

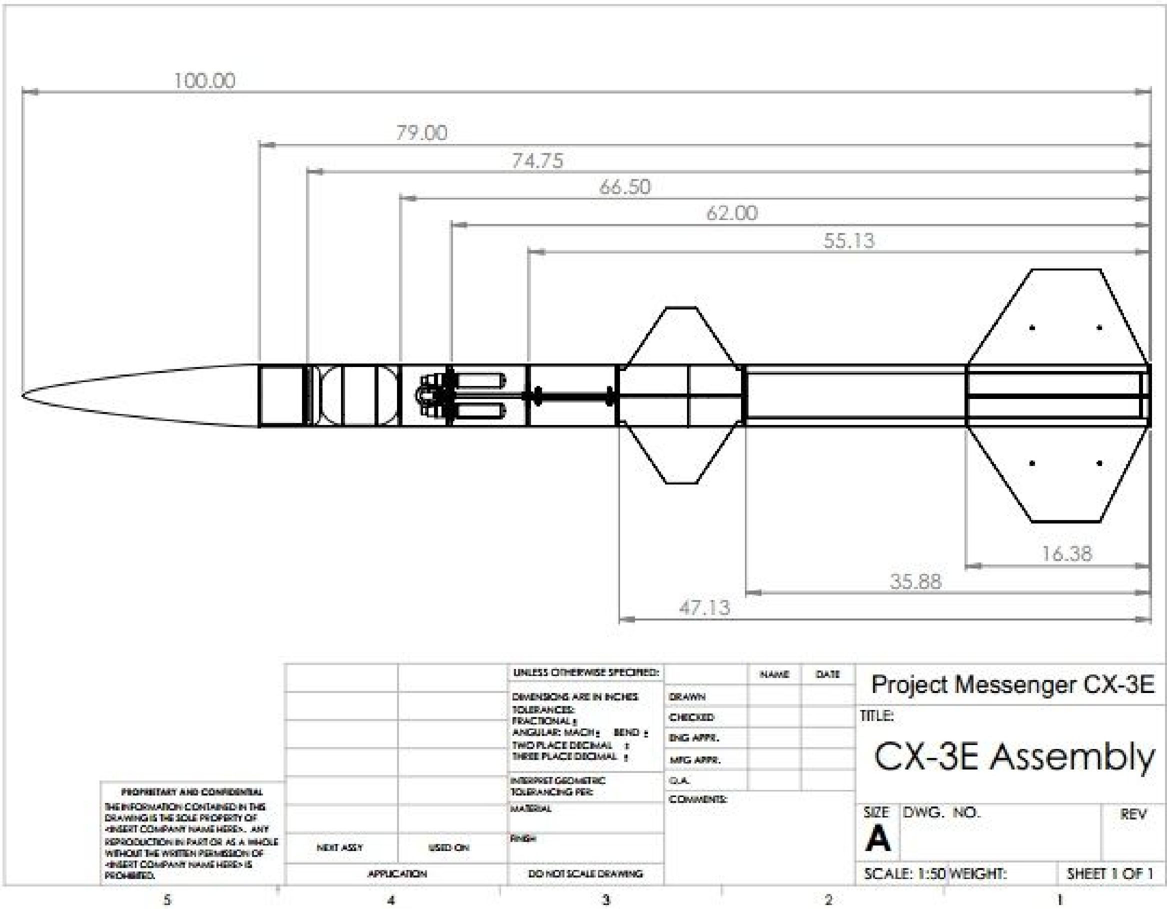
- ❑ Tamar places and HOLDS panel on rocket

- ❑ Sid screws panel back onto rocket

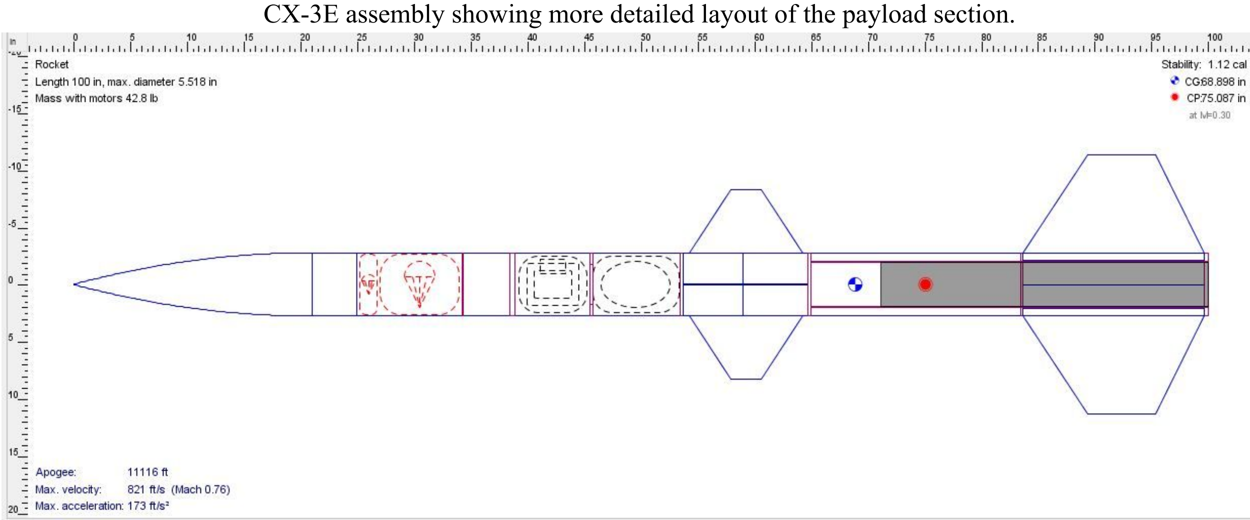
- ❑ Anim replaces igniter and places the alligator clips on

- ❑ Range is evacuated

Engineering Drawings Appendix



CX-3E assembly showing more detailed layout of the payload section.



CX-3E OpenRocket model showing location of center of gravity and center of pressure.

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Rob Davis

Lead Director - Harlem Launch Alliance