PROJECT SUMMARY

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CHANGE LOG

Group	Revision No.	Change No.	Description	Effective Date
Mgmt.	1.0	0	Initial document draft	1/13/2022
Mgmt.	1.2	1	Added operations concept figure and a high-level system diagram. Expanded descriptions of the spacecraft systems. Removed system engineering and added communication plan section. Added the IMP.	1/25/2022

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1 Introduction

1.1 Document Description

The following document outlines a summary of the ABEX mission aimed at providing a high-level picture of the major elements and implementation of the project. Specific technical details of the project, such as design parameters, requirements, etc. will generally not be shown.

1.2 Project Status

ABEX is currently in pre-phase A having just completed is proposal to NASA Astrophysics Research and Analysis program (APRA) for funding to being in October 2022.

1.3 Scope of Applicability

All specifics referenced or summarized in this document should see source documents for current details. Changes made since the publishing of this document can occur and formal documents will always take precedence over information contained within this.

1.4 Reference Documents

Formal project documents are being developed at this time. Main reference is the APRA 2021 proposal which can be provided upon request to the management team.

2 Mission Objectives

2.1 Mission Summary

The Alabama Burst Energetics eXplorer (ABEX) is a 12U CubeSat to study Gamma-ray Bursts (GRBs). The payload onboard ABEX is a suite of wide-field X-ray and gamma-ray detectors which will observe the prompt X-ray emission in GRBs to better understand their energy dissipation through observations of a new energy domain. The project is led by a consortium group of universities across the state of Alabama partnered with NASA Goddard Space Flight Center (GSFC). The payload and spacecraft are a union of commercial and in-house systems developed by the university teams with flight qualification testing provided by GSFC. The mission has been proposed to APRA 2021 with 4-years of development and 1-year of orbit operations.

2.2 Project Stakeholders

The ABEX project has several stakeholders whose goals will be addressed by the mission.

2.2.1 External Stakeholders

ABEX is a proposed mission to the Astrophysics Research and Analysis Program (APRA) under the NASA Science Mission Directorate (SMD). In addition, the university group working on ABEX was formed under the Alabama Statewide CubeSat Initiative (ASCI), which is a program sponsored by the Alabama Space Grant Consortium (ASGC) to develop CubeSats across the state of Alabama.

Table 1: Description of external stakeholders which are sponsoring and/or directly funding the ABEX project.

Stakeholder	Objectives and Goals
NASA Science Mission Directorate	Addresses goals in the NASA astrophysics roadmap, specifically Section 5 of revealing the extremes of nature through the study of black holes, accretion disks, and powerful jets. Address the need for engagement within a STEM pipeline to increase diversity in the field (synergistic with the NASA Strategic Plan, Objective 3.3).
Alabama Space Grant Consortium	Provide research opportunities for faculty and students (undergraduate and graduate) in the field of aerospace. Develop aerospace capabilities within the state of Alabama through training the new workforce with hands-on experiences in all aspects of project development and implementation. Conduct outreach and engagement with minority serving institutions.
Astrophysics Science Community	Address topics in the 2020 astrophysics decadal survey’s report on compact objects and energetic phenomena, specifically relevant subjects in B-Q2 and B-Q3 on compact objects and jets. Provide opportunities for minority institutions to be at the forefront of astrophysical research.

2.2.2 Internal Stakeholders

The project involves a union of universities across the state of Alabama and GSFC in the project. Supporting this core team are NASA services and commercial vendors. Finally, the results of ABEX will be provided to the science community consisting of researchers in NASA and academia.

Table 2: Description of internal stakeholders, known as participants, contributing to the project.

Participants	Objectives and Goals
Faculty	Provide class educational projects and graduate student research funding. Publish on project work and research.
Researchers	Provide relevant data for research in GRBs. Archive data for future usage.
Students (Graduate / Undergraduate)	Educate on aerospace and science topics to prepare for future work in industry, government, and academia. Provide research funding for graduate degrees and thesis/dissertation topics.
NASA GSFC	Engage with the SmallSat and science community through secondary payloads.

Participants	Objectives and Goals
NASA LSP	Provide a flexible launch option with easy integration into the CubeSat launch Initiative (CSLI) program.
Commercial Vendors	Provide flight capabilities for CubeSat missions.

2.3 Science Mission

2.3.1 Background

GRBs are highly energetic events of extragalactic origin observed as episodes of bright gamma-ray emission over periods of seconds to minutes. GRBs occur randomly in time and are isotropic in the sky. This prompt emission is followed by an afterglow period spanning the full electromagnetic spectrum lasting anywhere from days to months. GRBs originate from the formation of compact objects such as neutron stars and black holes. There are two types of GRBs distinguished by the time to achieve 90% of their emission (T90): short GRBs typically classified as T90 <2 s and long GRBs as T90 >2 s. Long GRBs are believed to be large stars undergoing a special kind of core collapse, whereas short GRBs are believed to be mergers of compact objects (neutron-star/neutron-star or black-hole/neutron-star mergers). In either type of GRB, the formation of a compact object creates the central engine that powers a relativistic jet generating the prompt and afterglow emission. Most GRBs emit a spectrum fit with an empirical model made from two smoothly joined power laws. However, each GRB is a unique event with a highly variable lightcurve (flux over time) and spectra.

2.3.2 Key Questions

The study of GRBs has many open questions which are summarized into a few Key Questions:

KQ1	**Key Question 1:** ***How is energy dissipated within the jet?*** The energy driving the GRB from the central engine can be dissipated to gamma rays through mechanisms such as internal shocks, magnetic reconnection, and heating by particle interaction.
KQ2	**Key Question 2:** ***What is the composition of the jet?*** The energy in the outflowing jet is carried by a combination of magnetic fields, baryonic matter, and photons. Two extremes of jet composition can exist: a baryon-dominated fireball or magnetic fields in Poynting-flux-dominated outflow.
KQ3	**Key Question 3:** ***What mechanisms are responsible for the prompt radiation?*** The prompt emission from a GRB jet is the result of several possible fundamental interactions including thermal blackbody emission, synchrotron radiation, inverse Compton scattering, and others.

Answering these questions requires an understanding of which physical models best explain the prompt emission. New observations are needed in the low-energy prompt emission to properly distinguish unique spectral features predicted between production models (internal shock and photospheric). These unique features are not observable with current and planned missions such as Fermi and Swift due to their instruments relatively high energy thresholds.

2.3.3 Objectives

ABEX has two scientific objectives in its study of GRBs:

- **Science Objective 1 (SO1):** *Distinguish between photospheric and internal shock models*
- **Science Objective 2 (SO2):** *Distinguish between local and continuous dissipation around the photosphere.*

Each of these science objectives are addressed through the exploration of the photospheric or internal shock model physical mechanisms and conditions on the location of energy dissipation. The mapping of these goals to parameters, observables, and the instrument and mission design requirements are shown in the Science Traceability Matrix (STM).

2.3.4 Science Traceability Matrix

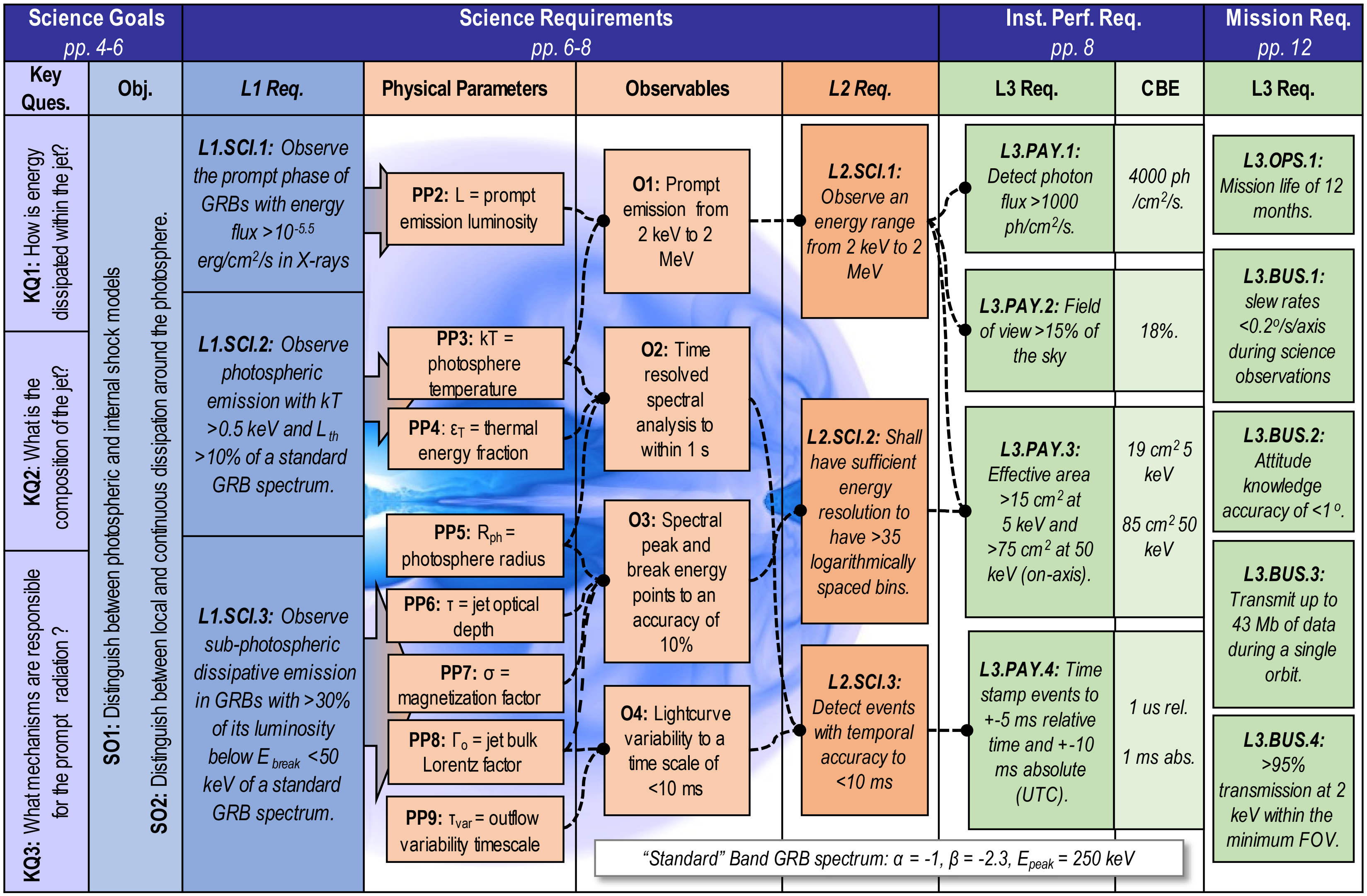

Figure 1: STM with ABEX which includes the science and instrument requirements. Page references cite the 2021 APRA proposal.

2.4 Educational Mission

ABEX will strategically enable 6 academic institutions with faculty, graduate, and undergraduate students in all project aspects. Faculty members advise graduate students who lead undergraduates in senior-level projects. ABEX will place graduate students in critical leadership and engineering roles for early career opportunities. Academic courses will be offered by ABEX faculty to educate students in specific topics relevant to each team. The ABEX project has a multidisciplinary and geographically disperse work environment, providing realistic working conditions compared to modern collaborative missions with students simultaneously gaining hands-on science and engineering skills and academic credits.

3 Instruments Overview

ABEX will fly a suite of instruments consisting of several X-ray and gamma-ray detectors to observe a large energy range and high field-of-view to capture the GRBs occurring isotopically in the sky. An overview of the physical layout and elements of the detectors are shown in Figure 2.

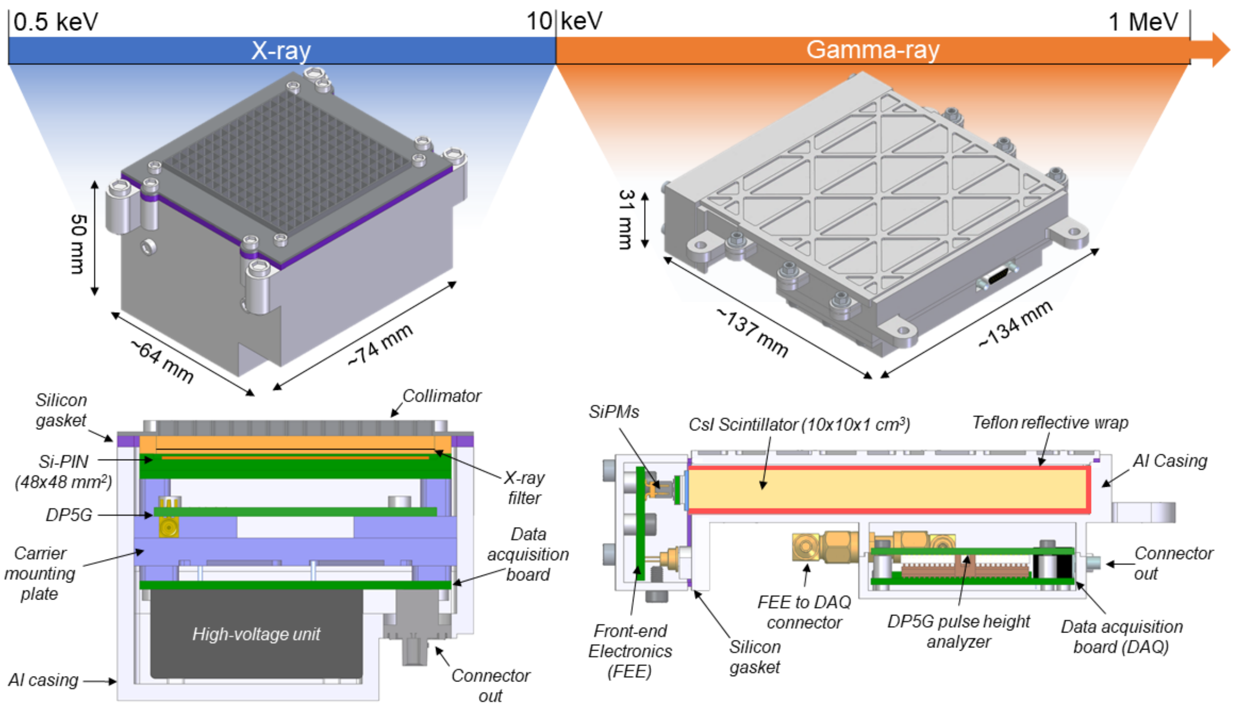

Figure 2: Overview of the detectors which comprise the instrument suite of ABEX. Major parts are called out with the relative energy ranges of each detector.

3.1 X-ray Detectors

The X-ray Detector (XRD) is a silicon Si-PIN sensor from Hamamatsu (S14536) with a 48x48 mm^2 sensitive area and thickness of 500 µm. Above the sensor is a gridded tungsten collimator that narrows the FOV to ~3% of the sky (per detector) for X-ray background reduction. Between the collimator and sensor is a Luxel thin film X-ray filter of 200 nm aluminum and 300 nm polyimide. Signals from the Si-PIN are amplified by front-end electronics and sent to a DP5G unit to be processed for pulse height to determine the energy and time of the event, known as digitization. Each XRD unit contains the high-voltage converter for the Si-PIN; digitized data is sent to the payload interface unit located in the spacecraft avionics stack.

3.2 Gamma-ray Detectors

The Gamma-ray Detector (GRD) is a crystal scintillator of cesium iodide coupled to an array of Silicon Photomultipliers (SiPMs). Each GRD features a high-voltage converter. Signals from the SiPM array are summed by front-end electronics and processed for pulse height to determine the energy and time of the event using the DP5G digitizer. The GRD data is sent to the payload interface unit located in the spacecraft avionics stack. The GRD provides a large FOV, seeing ~27% of the sky (per detector).

3.3 Payload Interface Unit

Both the XRD and GRD feed data into a Payload Interface Unit (PIU) inside the spacecraft avionics box. PIU detector control and event data storage are accomplished via a Xilinx System-on-Chip (SoC). Detector signals from the DP5Gs, high-voltage converters, and peripherals are multiplexed into communication buses read by the SoC. The PIU interfaces with the primary spacecraft computer for telemetry organization and ground commands including data and calibration requests.

4 Concept of Operations

The ABEX mission is to deliver science data which must be observed from orbit. The high-level view of the events and data flow is shown in Figure 3.

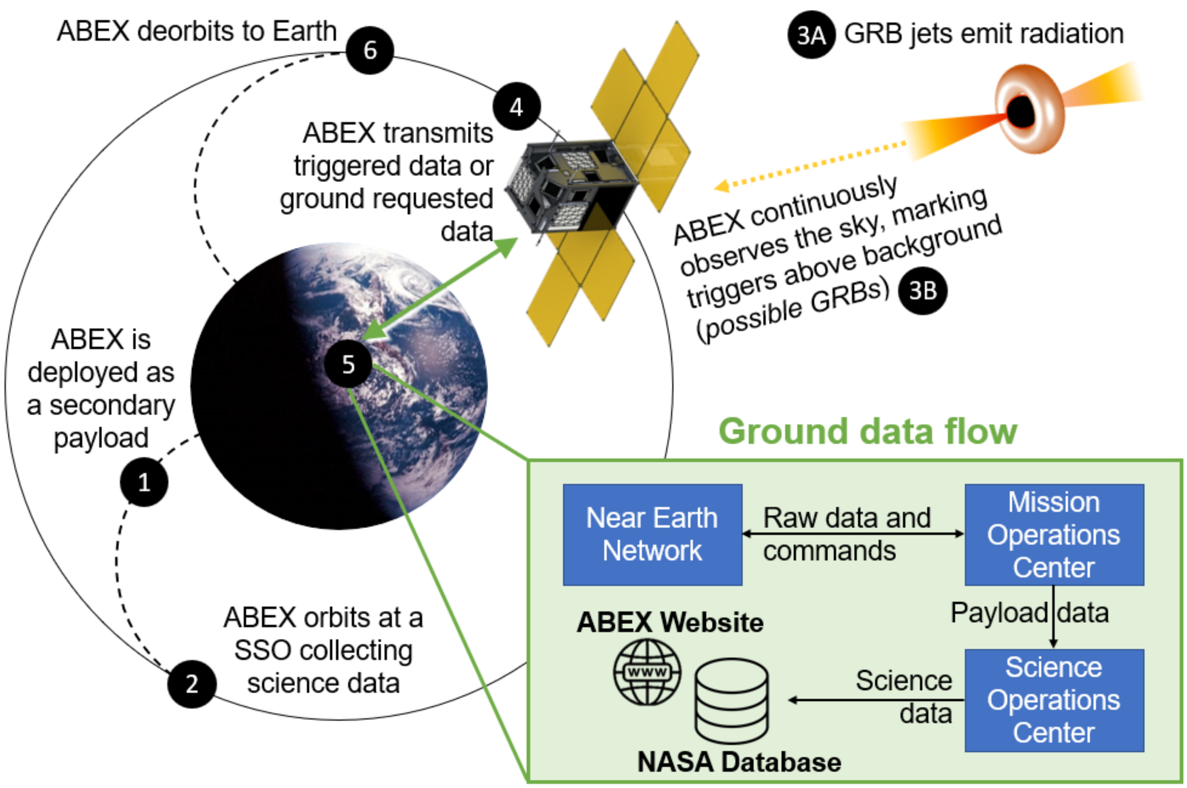

Figure 3: Overview of the general operation concept for the mission and data.

ABEX is planned to deploy to a Sun-Synchronous Orbit (SSO). The SSO is desirable for power generation simplicity, but deployment from the International Space Station (ISS) is possible. The SSO altitude selection depends on LV availability and collision risk with an upper limit of ~700 km to passively deorbit within 25 years. Science instruments in SSO collect GRB data while solar arrays maintain a sun-pointing vector. Data is downlinked twice per day to the Near Space Network (NSN) Alaska Satellite Facility with elevationdependent communication windows lasting between 6 and 9 minutes. Data collection is paused while traversing the South Atlantic Anomaly and High Latitude Zones, where higher background radiation exists. Science data is collected as time-stamped energy events and stored in a buffer. Event rates detected above a background threshold will automatically be downlinked with the full buffer data being requestable from the ground for up to 1 week prior (from last downlink) allowing sub-threshold searches, such as for weak gravitational wave events. All software operations are event-driven except for fixed deployment sequences and uplinked commands specified by the ground.

Table 3: Desired orbital parameters for a launch through the CSLI.

Mission Name	Mass [kg]	Desired Orbit		Acceptable Orbit Range	400 km @ 51.6⁰ incl. Acceptable?	Ready Date	Desired Mission Life
ABEX	25	Altitude [km]	600	400-700 km (SSO)	Yes	October 2026	1 year
		Inclination [deg]	98.3				

5 Spacecraft Overview

5.1 Summary & Architecture

ABEX is a CubeSat designed to Tyvak's 12U dispenser form factor but could accommodate a different dispenser as the LV requires. A 12U form factor is necessary to provide sufficient volume for the payload. The unique instrument mounting, power, and FOV requirements necessitate the development of a custom bus architecture engaging a union of COTS and in-house design solutions. An overview of the CAD assembly proposed is shown in Figure 3. The spacecraft nominally maintains a sun-pointing face with fixed, deployed solar arrays and two high temperature sun sensors, whereas the Earth-pointing face features the X/S-band antennas for communication. The other spacecraft faces feature detector arrays and/or attitude determination sensors such as a star tracker, GPS antenna, and sun sensors from Blue Canyon Technologies (BCT). Inside the spacecraft, most of the avionics systems are housed within a single avionics box with a battery box mounted directly to the avionics box. An internal overview is shown in Figure 4.

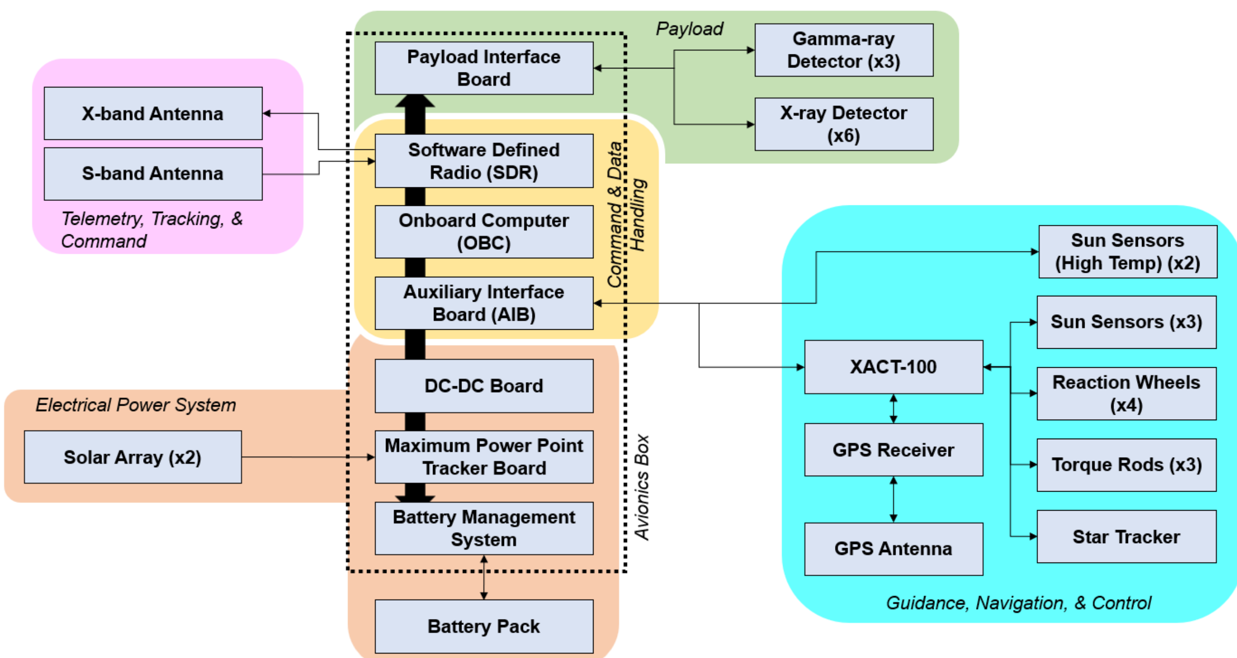

Figure 4: Simplified systems within ABEX. Lines show the interactions between them. Color groups are the system organization. Power is not shown for clarity along with thermal and physical mounting.

5.2 Spacecraft Subsystems

5.2.1 Structures & Mechanisms

All ABEX systems must be integrated into the allowed dispenser volume with structural mounting that can survive the launch environment. The dispenser specifications also dictate a maximum mass requirement and external spacecraft geometry requirements. The Structures & Mechanisms team is responsible for mounting design and supporting structural elements. Deployable solar arrays are needed to provide sufficient power during the mission; they are constrained in a stowed position using Hold & Release Mechanisms (H&RM) to fit within the dispenser volume until the execution of the deployment operational sequence releases the H&RMs. The structural design of ABEX has unique requirements dictated by the instrument suite. Each GRD and XRD must be mounted at distinct angles to maximize the total space field of view while avoiding spacecraft chassis elements, solar arrays, and the Earth. There must also be overlap between the XRD and GRD fields of view. Avionics systems, meaning flight electronics, are contained

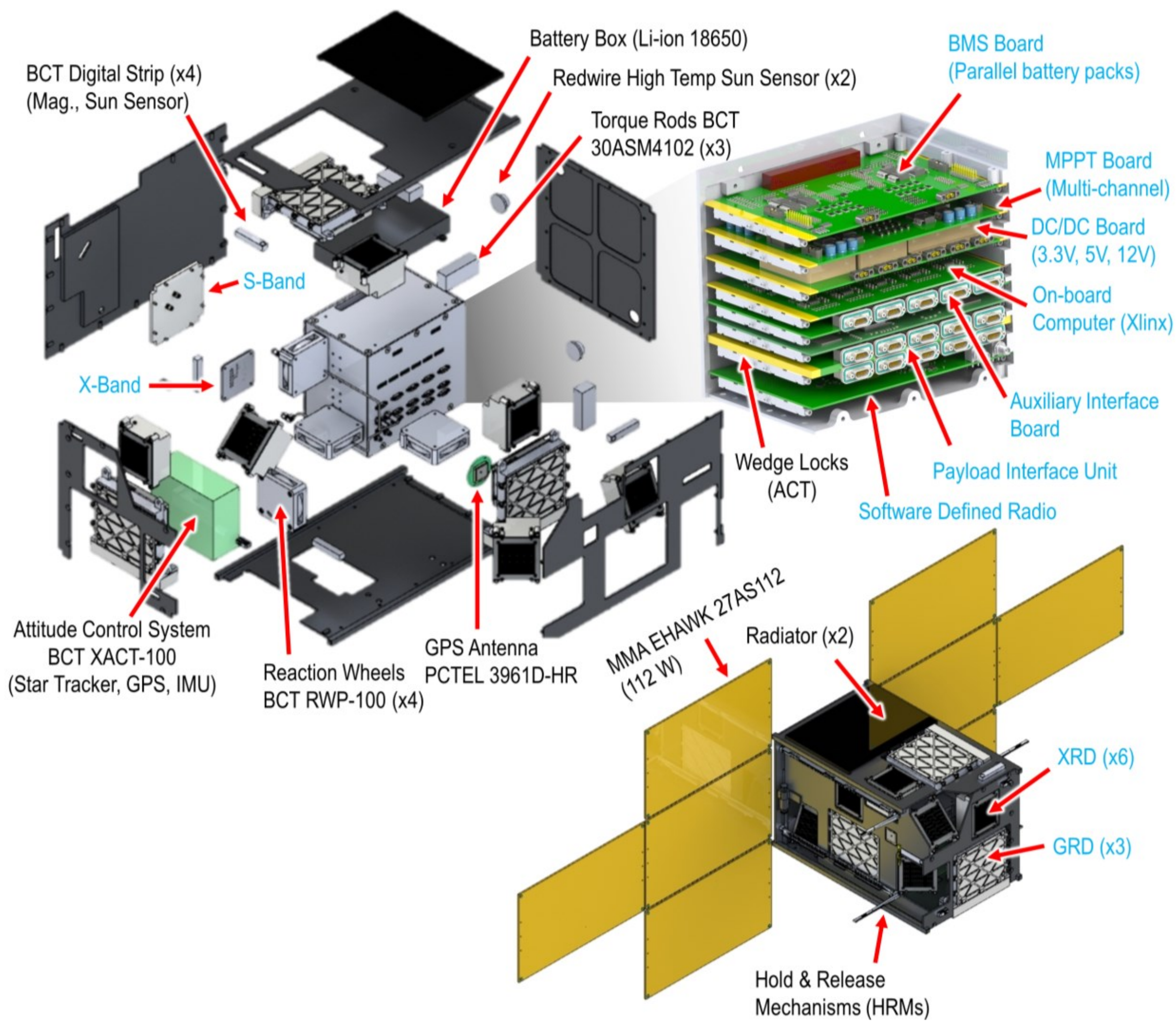

Figure 5: Overview of the spacecraft CAD with major elements highlighted. In blue are in-house systems planned to for development by the universities teams.

within a housing called the avionics box which provides structural support and thermal control. All other elements are mounted to the structural chassis.

5.2.2 Thermal Control

Thermal Control regulates conduction within the spacecraft and radiation between the satellite and its operational environment to ensure all systems remain within their hot and cold operational temperature limits when powered on and their extreme temperature limits when powered off. Thermal Control mechanisms include resistive heaters for active control, thermal coatings for radiation control, heat pipes for conduction control, and specialty mounting equipment inside the avionics box for electronics thermal management. The goal of Thermal Control analysis is to determine the required heater wattage and radiator area necessary to operate within the operational environment at the end of a spacecraft's life, not to predict the temperatures encountered at a given time.

5.2.3 Electrical Power System

The spacecraft power supplied by the solar arrays with power stored within battery cells. The raw power input is provided must be conditioned and distributed to each system in the spacecraft by the Electrical Power System (EPS). EPS consist of several boards which manage different aspects of the power system. The Battery Management System (BMS) handles power storage with the batteries controlling charging and sensing. The Maximum Power Point Tracking (MPPT) Board handles the main power distribution from both the solar and battery input, which is then provided for conditioning before output by the DC/DC Board. The DC/DC Board conditions the output from the MPPT Board to a several controlled voltage rails which are used by each of the spacecraft systems. The power systems, outside of the solar arrays, are being developed by the EPS Team. The solar arrays are planned to be provided by the commercial vendor MMA Design LLC (MMA) with associated hold and release mechanisms.

5.2.4 Command & Data Handling

The operation of the spacecraft is controlled by the On-Board Computer (OBC). The OBC has a controller which runs the Flight Software, executing commands to each system and storing generated spacecraft telemetry and relevant science data from the PIU for transmission. The OBC interfaces with the rest of the spacecraft systems through an Auxiliary Interface Board (AIB) which takes in data and connections from the other spacecraft/instrument systems and provides it to the OBC. In addition, the C&DH Team is also developing the Software Defined Radio (SDR) which both transmits and receives data through the X/S-band antennas respectively.

5.2.5 Telemetry, Tracking & Command

ABEX telemetry downlinked to Earth in X-band includes science data, diagnostics data, and event log data. Telemetry uplinked from Earth in S-band includes science data requests, software updates, and commands. All use cases with ABEX are enacted via commands. The ground station is the Near Space Network's (NSN) Alaska Satellite Facility (ASF). Communications windows with the NSN ASF last between 6-9 minutes depending on spacecraft elevation from the ground perspective. All data must be encoded using standards set by the Consultative Committee on Space Data Systems. Patch antennas developed by the Telemetry, Tracking, and Command (TT&C) team receive signals from the SDR to downlink an encoded radio signal.

5.2.6 Guidance, Navigation, & Control

The Guidance, Navigation, & Control (GN&C) system determines the spacecraft attitude, or orientation, using sun sensors, star trackers, inertial measurement units, and magnetometers, controls the spacecraft attitude using reaction wheels and torque rods, and consistently updates the spacecraft's time, position, and velocity information by interacting with Global Positioning System (GPS) satellites. The two sun-pointing sun sensors provided by Redwire are designed to withstand high temperatures; all other components except for the GPS receiver are provided by Blue Canyon Technologies (BCT). The BCT attitude control system is called the XACT-100 and features a central unit that both organizes and processes data from attitude sensors and provides control signals to attitude control components. Guidance and control logic must be processed in real time to maintain attitude stability.

5.2.7 Flight Software

The Flight Software (FSW) controls all spacecraft operations by interacting with data generated by each system, making decisions on that data, and commanding the spacecraft systems. Spacecraft FSW can enact sequential, event-driven, or ground-commanded modes of operation, and all but ground-commanded processes are autonomous. The software framework is F', an open-source platform from JPL, running on Linux. A spacecraft architecture is created using F'', a development language for F'. Modular architecture components are created with mission-specific commands, events, and telemetry. When a pin-specific design is known and component Interface Control Documents are provided, C++ is written to create design-specific functionality within the architecture. F' includes built-in tools for testing, commanding, and communicating with ground data systems.

6 Ground Systems Overview

6.1 Near Space Network

The ground station is provided by NASA through the NSN. The Alaska facility is planned for communicating to support the SSO. The NSN will provide scheduling and command uplinks in coordination with the Mission Operations Center (MOC), along with providing the downlinked raw data.

6.2 Science Operations Center

The instrument data is sent to the Science Operations Center (SOC) which generates the science data and provides instrument commanding and operations input for the science mission to the MOC.

6.3 Mission Operations Center

The main spacecraft operations are conducted through the Mission Operations Center (MOC) located at UAH. The MOC takes in the raw data from the NSN and processes the data for the operators and for the SOC. Mission commanding through the NSN is generated by the MOC. Orbital analysis during the mission is provided by the ABEX Orbit Team.

7 Management

7.1 Institution & Partnerships

The ABEX project brings together several institutions, with many faculty each leading specific ABEX teams. Each team has student involvement in the form of either senior design (one or two semesters), research projects, or volunteer effort. Select teams have graduate students which lead their team's work effort with advisement by the faculty member. The breakdown of institutions, project teams at those institutions, and a summary scope of work for each team is shown in Table 4.

Table 4: Institution, teams, and a brief scope of work description highlighting the major tasks for that team.

Institution	ABEX Team	Scope of Work
University of Alabama in Huntsville	Management	Management of the project.
	System Engineering	Development of systems model. Management of system engineering products, interface control, and technical advisement.
	Science	Science mission and data product generation. Development of science requirements. Advisement of the payload design for science return. Manages the instruments during operations.
	Payload (PAY)	Design, analysis, and assembly of the instrument suite.
	Operations (OPS)	Management of the spacecraft during operations.
	Integration, Assembly, & Testing (IA&T)	Leads the system-level integration and testing. Coordinates assembly tasks.
University of Alabama	Electrical Power System (EPS)	Design, analysis, and assembly of the EPS.
	Command & Data Handling (C&DH)	Design, analysis, and assembly of the OBC, SDR, and AIB.
University of South Alabama	Telemetry, Tracking, & Command (TT&C)	Design, analysis, and assembly of the X/S-band antenna.
	Guidance, Navigation, & Control (GN&C)	Selection and analysis of GN&C systems. Provides design input on the attitude control elements of the software.
Auburn University	Flight Software (FSW)	Flight software development and maintenance during the mission.
	Structures & Mechanisms (S&M)	Design and analysis of the structural elements and configuration of the spacecraft assembly.
	Thermal Control (TRM)	Design of the thermal systems and thermal analysis of the spacecraft assembly.
	Astrodynamics (AST)	Orbital analysis during mission design and operations.
Alabama A&M University	*Working directly under UAH teams*	Design support and outreach.
Drake State Technical & Community College	*Working directly with the IA&T team at UAH*	Spacecraft flight assembly and supplying the cleanroom.
Goddard Space Flight Center	Flight Qualification	System level flight qualification testing.

The project is also supported by a Science Advisory Board which provides input into the science mission and requirements, and a Subject Matter Experts Panel which provides technical advisement and review for the project.

7.2 Organizational Structure

The several teams of ABEX are lead through a management hierarchy shown in Figure 6.

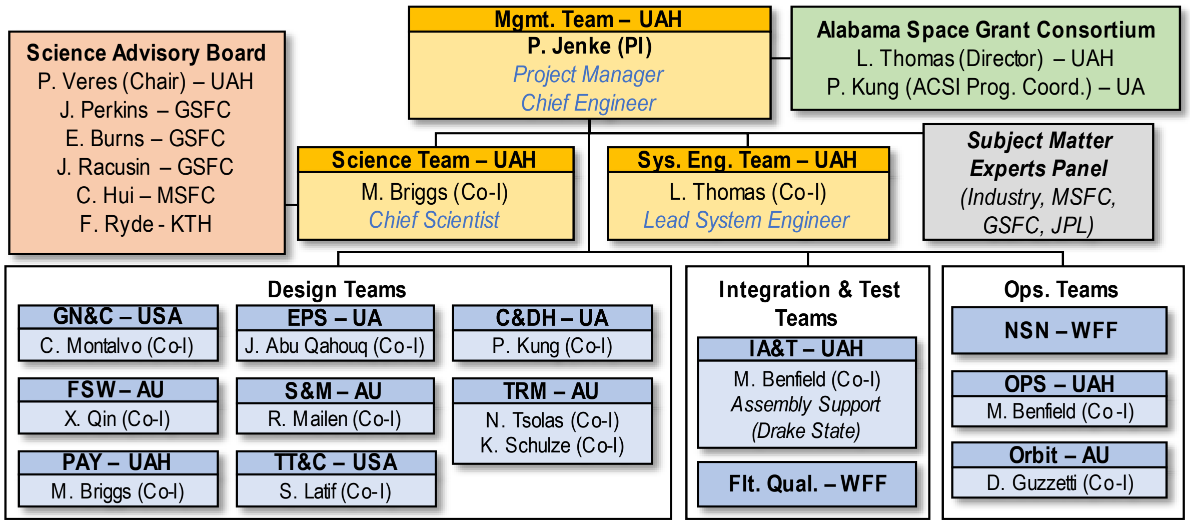

Figure 6: Project leadership hierarchy and faculty assignment.

The management and execution of the project on a day-to-day basis involves several key roles in the project leadership, which is shared between faculty and students, described in Table 5.

Table 5: Key project leadership roles and short description of their responsibilities.

Project Role	Type	Responsibility
Principal Investigator (PI)	*Faculty*	Leads decision making for the project concerning major budget and timeline decisions. Ensures that the scientific and educational objectives are met.
Project Manager (PM)	*Graduate Student*	Leads process and work task planning, budgeting, and advises decision making for the PI.
Chief Engineer (CE)	*Graduate Student*	Leads the engineering design of the spacecraft and payload integration, advising technical decision making and ensuring verification and validation of the design. Advises decision making for the PI.
Lead System Engineer (LSE)	*Graduate Student*	Leads the development and maintenance of the integrated systems model and publishing of system engineering products. Advises decision making for the PI with faculty lead.
Chief Scientist (CS)	*Graduate Student*	Leads the development of the science mission with associated requirements. Supports data analysis and payload instrument simulation. Advises the PI and payload engineering team for scientific return.
Faculty Team Lead	*Faculty*	Leads their team and responsible for delivery of work products, while advising and coordinating student labor.

7.3 Communication Plan

The ABEX project must communicate technical and programmatic information between several disparate teams, this is accomplished by several methods. Formal communication will occur over email. Informal communication will occur through the Slack workspace, which has several channels for each project team and interface channels between common system integration points. Group wide updates are held on a bi-weekly basis over a Zoom telecon where progress is reported, and general questions and issues are brought up. In addition, biweekly meetings will be held between the teams and the management and system engineering for detailed updates.

7.4 Data Management Plan

ABEX will generate several levels of scientific data which will be processed both automatically and by the science team. The level 0 data consist of the raw packet files from the NSN provided to the ABEX mission operations center, from there it is processed into different levels of data organization. Level 1 and 2 data products consist of detector event data, calibration files, and detector response matrices needed for data analysis, along with trigger data for the community. Level 3 data will be cataloged events published at the end of flight. All data will be available on the ABEX website and at the High Energy Astrophysics Science Archive Research Center. ABEX will also provide science analysis tools for the community to process data into common formats needed for general analysis and visualization.

8 Timeline

The ABEX development schedule has 4 years of development and 1 year of flight organized into phases with critical reviews adapted from NPR 7123.1C. Built into the schedule and budget is 8 months of margin for phases A-C and another 8 months of margin during phase D. Travel is limited to critical testing events and conferences for data conclusion publication. FlatSat testing occurs at UAH with limited travel to deliver hardware. System-level qualification occurs at GSFC with the UAH mgmt., SE team, and IA&T team supporting. Following qualification testing, the IA&T team will deliver the qualified spacecraft to the launch integrator. The full timeline is contingent on funding selection, for the detailed integrated master plan (IMP) see the ABEX APRA 2021 proposal. Since selection will drive the ABEX formal start into phase A, the schedule start is subject to change pending selection. The IMP is shown in Figure 7.

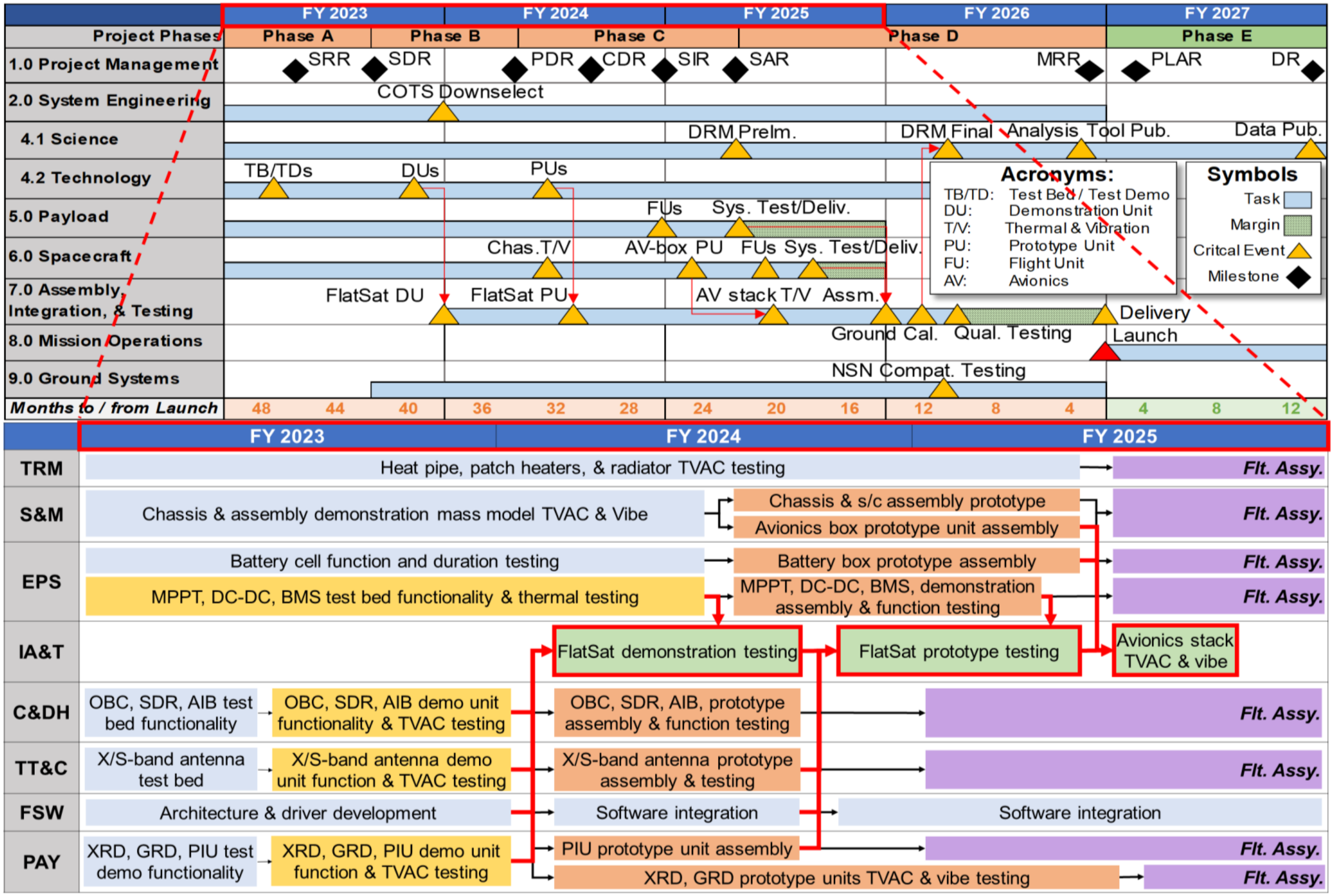

Figure 7: ABEX IMP showing the major events and testing flow. Yellow is demonstration assemblies. Orange is prototype assemblies. Green is integration tests. Blue is general test articles.

9 Appendix

9.1 Acronyms List

Acronym	Definition
ABEX	Alabama Burst Energetics Explorer
APRA	Astrophysics Research & Analysis
ASGC	Alabama Space Grant Consortium
CAD	Computer-Aided Design
C&DH	Command & Data Handling
CDR	Critical Design Review
CE	Chief Engineer
CLB	Configurable Logic Block
COTS	Commercial Off The Shelf
CS	Chief Scientist
CSLI	CubeSat Launch Initiative
DAC	Design Analysis Cycle
EAR	Export Administration Regulations
EPMs	Educational Performance Measures
EPS	Electrical Power System
FPGA	Field Programmable Gate Array
FSW	Flight Software
GN&C	Guidance, Navigation, & Control
GPS	Global Positioning System
GRB	Gamma-ray Burst
GRD	Gamma-ray Detector
HV	High Voltage
ICP	Instrument Calibration Plan

Acronym	Definition
IMS	Integrated Master Schedule
IMU	Inertial Measurement Unit
ISM	Integrated Systems Model
ITAR	International Traffic in Arms Regulations
KDP	Key Decision Point
KPPs	Key Performance Parameters
LSE	Lead System Engineer
MBSE	Models Based System Engineering
MCR	Mission Concept Review
NDA	Non-Disclosure Agreement
NIST	National Institute of Standards and Technology
PC	Program Coordinator
PDR	Preliminary Design Review
PIU	Payload Interface Unit
PM	Project Manager
POP	Period of Performance
QPSK	Quadrature Phase Shift Keying
SE	Systems Engineering
SEMP	System Engineering Management Plan
SIS	Software Interface Specification
SME	Subject Matter Expert
SMP	Software Management Plan
SQP	Structural Qualification Plan
SQR	Structural Qualification Report
SRD	System Requirements Document
SRR	System Requirements Review
STDP	Subsystem Technology Development Plan

Acronym	Definition
STP	Subsystem Testing Plan
TCP	Technology Control Plan
TID	Total Ionizing Dose
TPM	Technical Performance Measure
TQP	Thermal Qualification Plan
TQR	Thermal Qualification Report
TRL	Technology Readiness Level
TT&C	Telemetry, Tracking, & Command
V&V	Verification and Validation
WBS	Work Breakdown Structure
XRD	X-ray Detector