University of Colorado Boulder

Department of Aerospace Engineering Sciences

ASEN 4018

Project Definition Document (PDD)

Docking Arm Integration System for ScoutCam Camera (DAISy Cam)

Approvals

Relation	Name	Affiliation	Approved	Date
Customer	Rebeca Griego and Jon Buschur	Astroscale		
Course Coordinator	Kathryn Wingate and Chris Muldrow	CU/AES		

I. Project Customers

Name	Address	Phone
Astroscale	Astroscale U.S. Inc. 2201 S Delaware St, Denver, CO 80223	

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II. Team Members

Team Member	Phone Number	Email	Team Role
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Nate Sanchez		nathaniel.sanchez@colorado.edu	Mechanical Sub/Manufacturing Sub

III. Problem Statement

As more satellites are launched into orbit every year, the issue of space debris inhibiting successful missions grows larger. Geosynchronous orbits (GEO) and low earth orbits (LEO) are of special concern for their vital role in a variety of applications including GPS, communication, and surveillance. As these orbits grow more congested, the likelihood of dangerous collisions increases. Although debris removal is often employed as the primary solution for this issue, in certain cases it is more effective to attempt extending the life of the satellite to prevent the need for additional launches. Astroscale's Life-Extension-In-Orbit (LEXI) satellite seeks to prolong the operational life of commercial telecommunication and government satellites via power system extension. A critical requirement for this system is the need to monitor the successful docking of LEXI to a client vehicle.

To ensure successful satellite rendezvous attempts, Astroscale will integrate a ScoutCam camera to their docking system to monitor the process in real time. This is the mission of the Docking Arm Integration System for ScoutCam Camera (DAISy Cam) team. DAISy Cam seeks to develop, test, and integrate a system that will interface the ScoutCam device onto the LEXI docking arms. This will involve the creation of a harnessing system to securely attach the camera with the docking arm, as well as the procurement of a GEO-rated video card to provide camera data.

IV. Previous Work

A. Astroscale

The LEXI satellite possesses the ability to rendezvous and dock with a client satellite via LiDAR sensors and 6 degree-of-freedom chemical propulsion. Once attached, the docking arms maintain rigid connection while LEXI's power system extends the life of the vehicle. Electrical Propulsion (EP) systems enable LEXI to station keep across different vehicle masses and conduct transfer orbits between vehicles. The docking system design allows LEXI to dock with a wide variety of vehicles many times. The 120 degree wide field of view of the ScoutCam Starter Kit Probe docking camera is used to monitor the docking mechanisms client capture.

B. SpaceLogistics

SpaceLogistics, a subsidiary of Northrop Grumman, launched a satellite servicing vehicle named MEV (Mission Extension Vehicle) in 2019. MEV-1 will be servicing satellite IntelSat 901 for five years. MEV-1 is meant to dock with satellites whose fuel is almost depleted and take control of their orbit. MEV-1 does so with a reliable and low-risk docking mechanism that attaches to the client's vehicle. Throughout the docking process, MEV-1 utilizes the use of six cameras to assist with long-range vehicle detection, tracking, close range inspection, and navigation.

V. Specific Objectives

The objective of this product is to provide life-extension and end of life services to spacecraft orbiting the Earth. Much of the design to achieve this goal has been completed already; the job of the DAISy cam team is to integrate the provided ScoutCam camera with the docking arm structure and to design a video card solution that survives working conditions.

The first deliverable will be the integration of the camera, video card, and docking arm. This deliverable will be considered successful if the system designed can be harnessed onto a model of the docking arm. The camera should be mounted at the end of the arm and not interfere with the docking mechanisms.

The second deliverable will be the video card design. This deliverable will be considered successful if the video card is able to support multiple docking arm cameras and survive the radiation encountered in LEXI's lifespan. The levels of success will be determined primarily by how long the video card is able to survive under expected working conditions, and secondarily by the number of cameras it is able to support.

The third deliverable will be the output of the video from the video card. This deliverable will be considered successful if the video output from the system is compressed by a standard routine. The levels of success will be determined by how much compression is needed to be used for the output, with lower compression amounts and higher transmit rates being preferred.

The success levels are outlined for the project as shown below. Level one indicates the minimum requirements to be accomplished in order to be considered successful and level two indicates the requirements needed to achieve a higher level of success given the scope of the project.

Project Element	**Level 1 (Threshold)**	**Level 2 (Objective)**
Docking Arm Model	Half-scale model of docking arms using materials comparable with actual design.	Full-scale model of docking arms using exact materials from actual design.
Video Card Hardware	Video card supports 15 year GEO mission, uses SpaceWire connections, is no larger than 10"x1.1"x6.5" and has a 1-1 partially radiation-hardened replaceable counterpart.	Video card supports 18 year GEO mission, uses SpaceWire connections, is smaller than dimensions given in level 1 (TBD) and has a 1-1 fully radiation-hardened replaceable counterpart.
Camera-Arm Integration	Integration system secures camera to the end of the arm without interfering with docking mechanism. Minor changes to docking arm design are necessary.	Integration system secures camera to the end of the arm without interfering with docking mechanism. Little or no change to docking arm design required.
Simulation & Testing	Testing regime simulates vibrations similar to launch, and tests thermal capability to a range of 0-50 ^{o}C.	Testing regime simulates vibrations experienced during launch and tests thermal capability to a range beyond the threshold in level 1 (TBD).
Software	Software algorithms will compress and store video data reliably.	Software algorithms compress video data using JPEG2000 and store it reliably.
Shielding & Insulation	Thermal insulation maintains electronics temperature within range given in Level 1 of simulation element. Radiation shielded solution allows video card to last for 15 year mission duration.	Thermal insulation maintains electronics temperature within range given in Level 2 of simulation element. If video card is fully radiation hardened, no shielding will be necessary.

Table 1 Specific objectives

VI. High-Level & Functional Requirements

A. High-Level Requirements

- A physical model of the LEXI docking arms shall be created for testing and demonstration purposes.
- Research shall be conducted on the procurement of a GEO rated video card to read in data from four cameras.
- A thorough testing regime shall be developed to validate the structural and thermal capabilities of the system.

B. Functional Requirements

- Docking arm integration requirements provided by the customer:
    1) The camera shall be integrated into the current design of the docking arms.

- Astroscale has an already developed model for the docking arm that shall only be modified to secure the camera.

2) The camera shall be at the end of the docking arm without interference of the docking mechanism.
   - The camera is meant to monitor the docking process and should not hinder LEXI's ability to dock with client satellites.
3) The integration of the camera shall provide harness routing for the current docking arm design.
   - The camera wiring shall be integrated to the current arm model without need for major arm design changes or interference with the current arm's range of motion.
4) Integration shall be completed on a half or full-scale version of the docking arms.
   - Depending on the amount of material available and manufacturing tools at disposal, at half/full scale model shall be produced.

- Video card requirements provided by the customer:
  1) The video card solution shall function for a 15-year GEO mission.
     - LEXI is designed to function for 15 years servicing client satellites.
  2) The video card solution shall be able to support a minimum of 4 cameras.
     - LEXI possesses 4 docking arms and the video card shall be able to transmit visual data from cameras onboard all 4 arms.
  3) The video card solution shall be capable of performing compression of the camera output.
     - In the case that the camera output requires compression, the video card must be able to do so (preferred method is JPEG2000).

C. CONOPS

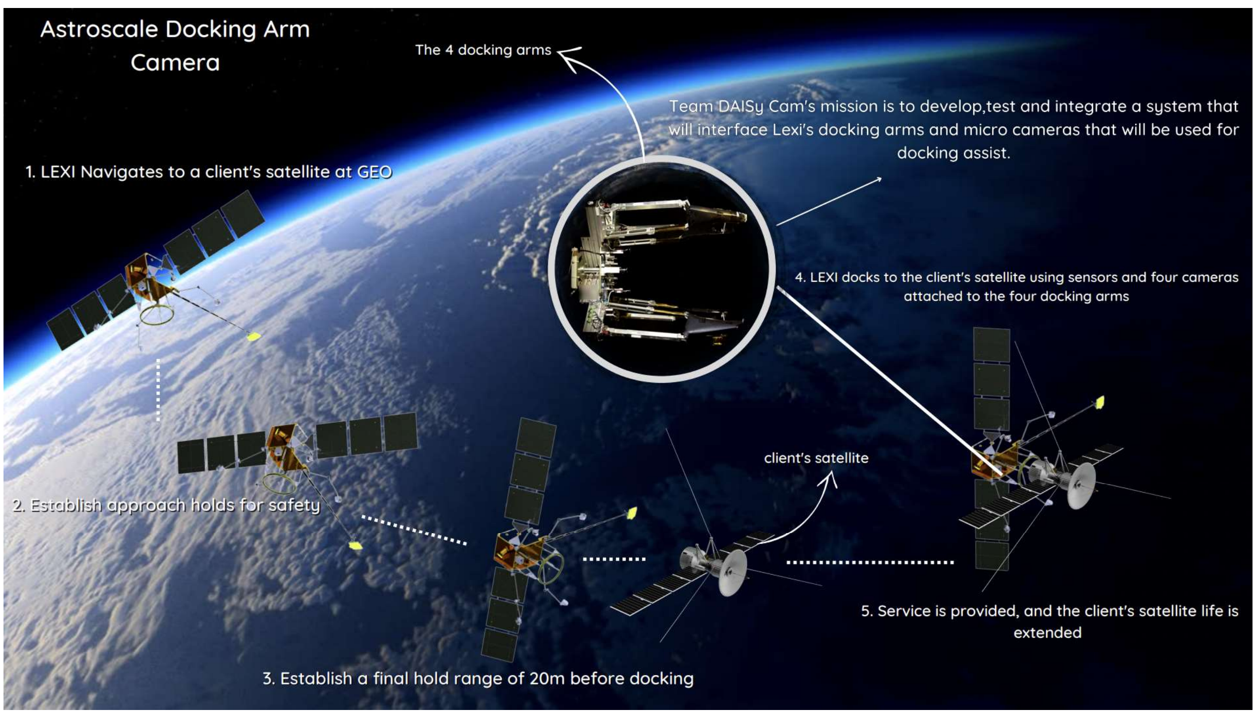

Fig. 1 CONOPS for LEXI

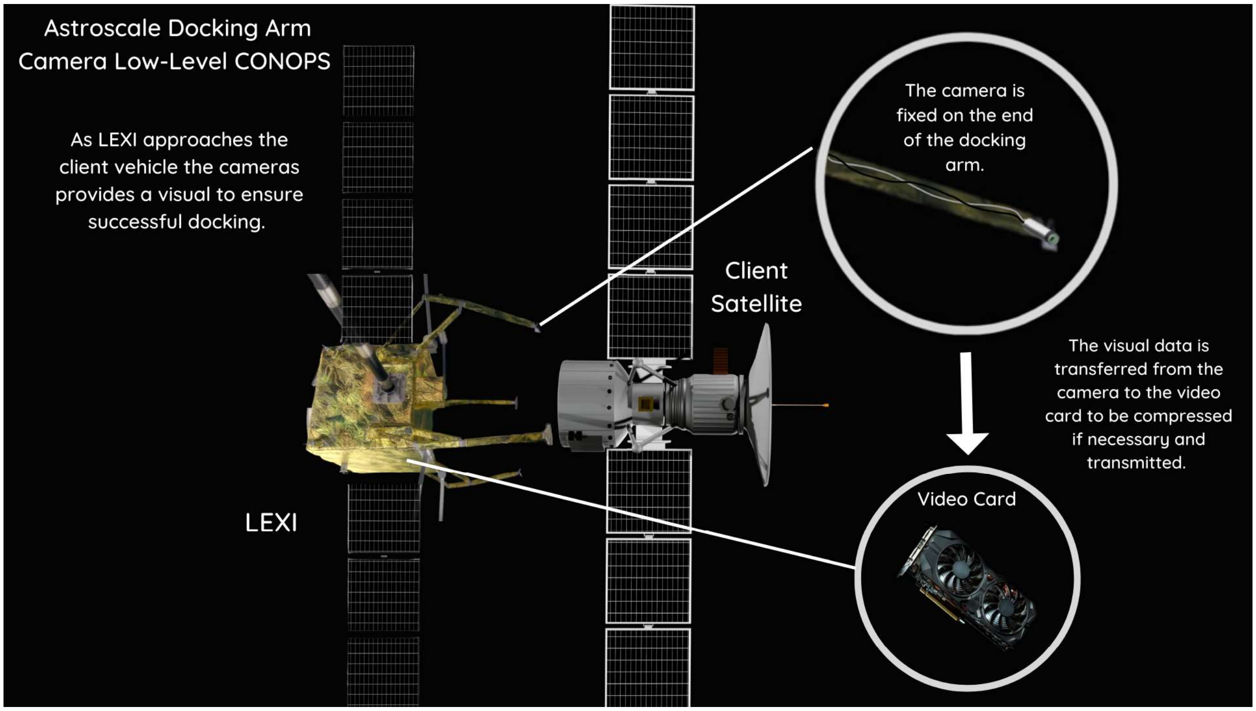

Fig. 2   CONOPS for LEXI Docking Arm

The concept of operations (CONOPS) details the mission objectives at a high level. LEXI must navigate and rendezvous with a client spacecraft, establish several hold ranges for safety, dock with the spacecraft, and finally provide life-extension or end-of-life services to the client spacecraft. The DAISy Cam team aims to assist with the docking process by designing and integrating video card systems to the cameras and docking arms of LEXI. This will allow for video transmission that will aid in guiding the docking arms to their desired position to latch onto a client spacecraft and provide the necessary services.

VII. Critical Project Elements

CPE Number	Critical Project Element	Explanation
Technical		
T.1	Electronic Harnessing	The docking arm must be able to function not only with the camera attached, but also with the electrical harnessing required to keep the camera operational. This harness must not interfere with the docking process either.
T.2	Physical Model Development	The model of the arm must be adjusted to encompass the camera at the end of the docking arm and simulate either a half or full-scale model of the arm. The model must be as accurate as possible to ensure that the solution is valid with the provided design.
T.3	Algorithm Development	The algorithm needs to be capable of performing video compression when required, as well as properly transmitting the video data. Failure of the algorithm could result in invalid or incomplete video data.
T.4	Research of Radiation Hardening	The 1-to-1 radiation-hardened replacement video card solution must be able to withstand the radiation at GEO for the duration of LEXI's usage. If the components are not able to handle the high radiation loads, there could be adverse affects on the functionality of the video card system.
T.5	Thermal Insulation	The video card solution must withstand the fluctuations in temperature experienced at GEO to ensure the integrity and proper functioning of the electronics and their data.
T.6	Camera-Arm Integration Development	A model of the physical connection between the docking arm and camera must be designed and manufactured in order to test functionality of the integration of the camera and harnessing to the docking arm.
T.7	Video Card Solution	The solution must be able to reliably collect, process, and store video data for the duration of the mission. Failure of the solution to ensure the integrity of the data collection, processing, or storing will result in unusable video data.
Logistic		
L.1	Manufacturing Space	Each arm is approximately 1-meter long at full-scale. Developing a full-scale model of the arm may require a large manufacturing space and large tools that may not be accessible. This will be one deciding factor of whether a half or full-scale model is developed.
L.2	Professional Manufacturing Sources	Developing a full-scale model of the arm may require professional assistance to manufacture. This will be a deciding factor of whether a rigid or flexible arm model is fabricated.
Financial		
F.1	Manufacturing Materials	When developing the scale model of the docking arm and choosing the material to construct it out of, the cost of material must fit within the portion of the budget allocated to manufacturing materials.
F.2	Video Card Materials	The cost of materials for the video card must fall within the section of the budget set aside for the video card solution.

VIII. Sub-System Breakdown and Interdependencies

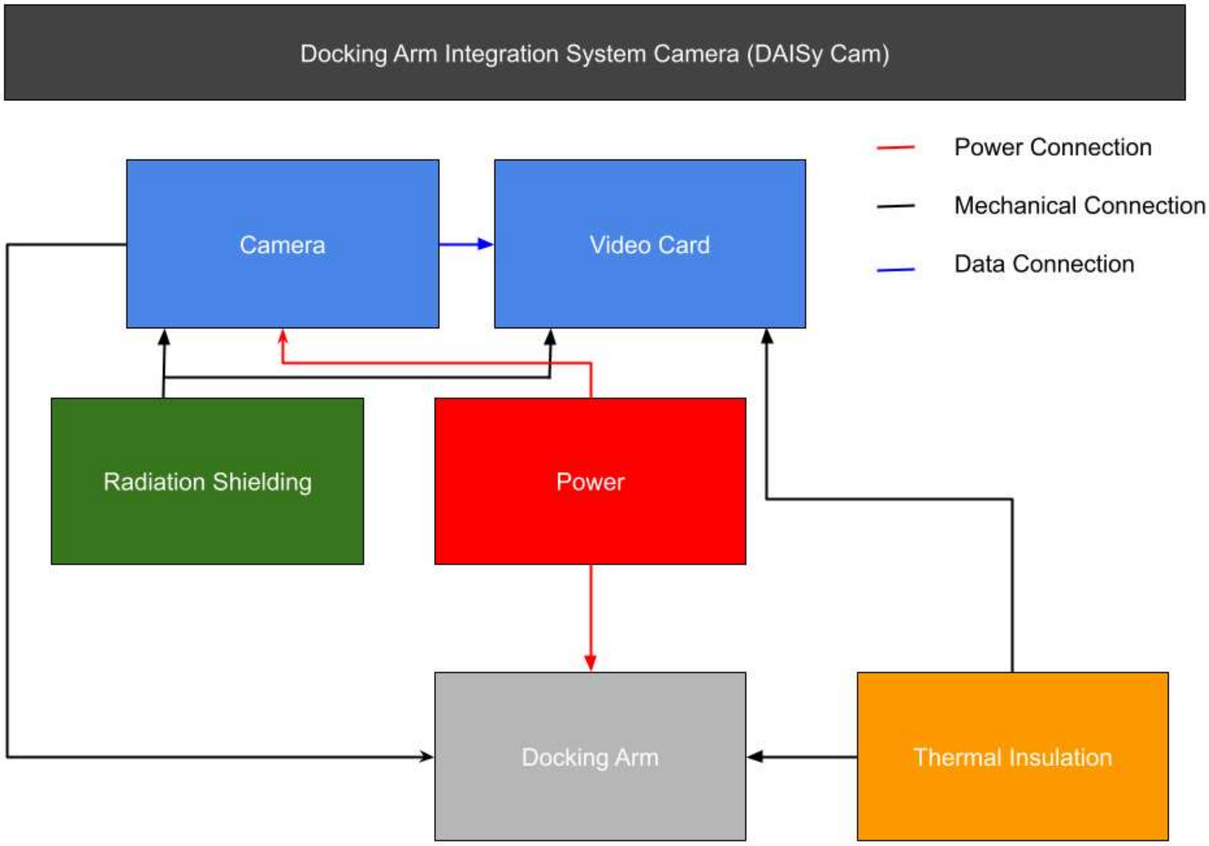

Fig. 3 Preliminary Sub-system Breakdown for DAISy Cam

IX. Team Skills and Interests

Team Member	Skills and Interests	Critical Project Element
Kiley Beckwith	Project Management, Designing, Manufacturing	T.2, T.4, T.5, L.1, L.2
Samuel Barrette	Systems Engineering, Programming, SOLIDWORKS, ANSYS	T.3, T.4, T.5, T.6
Mohhamed Alnasser	Designing, AutoCAD, SOLIDWORKS, Manufacturing,	T.1, T.2, T.4, L.1
Abby Durell	SOLIDWORKS Development, Part Integration, Manufacturing	T.1, T.2, T.6, L.1, F.1
Peyton Early	Programming, Electronics Fabrication, Problem Solving	T.3, T.4, T.5, T.7, F.2
Lucas House	Physical Model, Electrical Wiring, Manufacturing	T.1, T.2, T.6, L.1, F.1
Ketan Kamat	Electrical Design,Programming	T.1,T.3,T.5,F.2
Mason Lemler	Electrtical Design, Programming, Harnessing	T.1, T.3, T.6, T.7, L.2, F.2
Jacob Moncada	Soldering, Electrical Design, Finance	T.1, T.4, T.5, T.7, F.1, F.2
Nate Sanchez	AutoCAD, SOLIDWORKS, Manufacturing, Wire Harnessing	T.1, T.2, T.6, F.1, L.1

X. Resources

Critical Project Element	Resource/Source
T.1	Electronics Shop
T.2	Machine Shop, Fab Lab, SOLIDWORKS Arm from Astroscale
T.3	CU Computer Science Department
T.4	Outside vendor with cost effective solution
T.5	Dennis Akos - Professor at CU knowledgeable in astrodynamics and satellite navigation
T.6	SOLIDWORKS Arm from Astroscale, Machine Shop, Fab Lab
T.7	Dennis Akos - Professor at CU knowledgeable in astrodynamics and satellite navigation
L.1	AERO Building
L.2	KatieRae Williamson, Machine Shop
F.1	Project funding and Jacquelyn Stang, the CU aerospace finance and accounting professional
F.2	Project funding and Jacquelyn Stang, the CU aerospace finance and accounting professional

XI. References

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[4] "Mission Extension Vehicle (MEV) - Northrop Grumman". Northrop Grumman.https://www.northropgrumman.com/wp-content/uploads/Mission-Extension-Vehicle-MEV-fact-sheet.pdf

[5] Staples, Rob. "Key Capabilities of our Life Extension In-orbit (LEXI) Servicer". Astroscale. October 05, 2021. https://astroscale-us.com/lexi-life-extension-capabilities/