COE CST Seventh Annual Technical Meeting

Task #319. DebriSat Panel Preparation and Fragment Characterization for the Period: FY17 Q3

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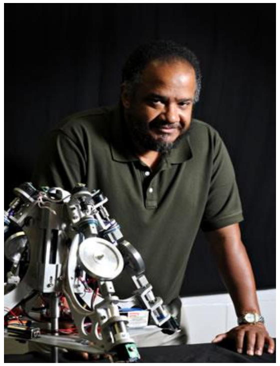
Las Cruces, NM

COE CST
Center of Excellence for Commercial Space Transportation

Agenda

- Team Members
- Task Description
- Schedule
- Goals
- Task Discussion
- Conclusions and Future Work

Team Members



- People
  - Norman Fitz-Coy (PI)
  - Joe Kleespies (Grad Student)
- Organizations

Task Description

- Objectives:
  - Implement "big data" management solution and procedures for archiving DebriSat's data.
  - Ensure all project data management requirements are satisfied.
  - Evaluate and optimize the performance of the data management solution.
  - Facilitate the transfer of DebriSat data to the project stakeholders.

Schedule

Semester	Tasks
Fall 2016	• Research viable database engines and storage methods. • Install and configure new database engine. • Define and document structure of new database engine and subsequent relational tables. • Begin modification of the existing DCS front-end layer.
Spring 2017	• Complete modification of the existing DCS front-end layer. • Implement new image and file storage structure. • Begin addition of “3D” imaging system fields and formats.
Summer 2017	• Evaluate and optimize database engine performance.
Fall 2017	• Complete addition of “3D” imaging system fields and formats. • Begin documentation of upgrade process and maintenance protocols.
Spring 2018	• Complete documentation of upgrade process and maintenance protocols.

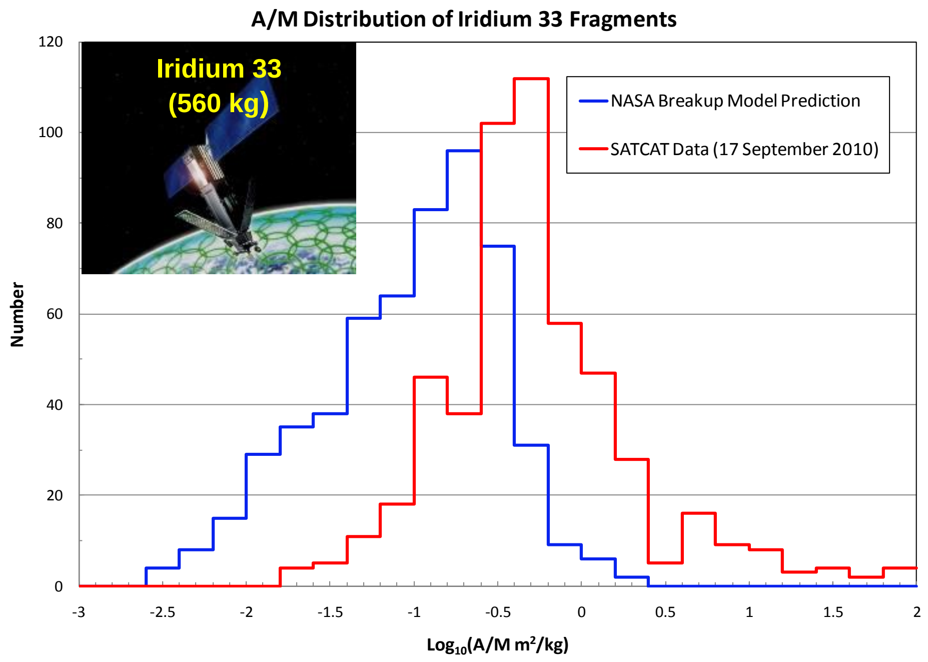
Goals

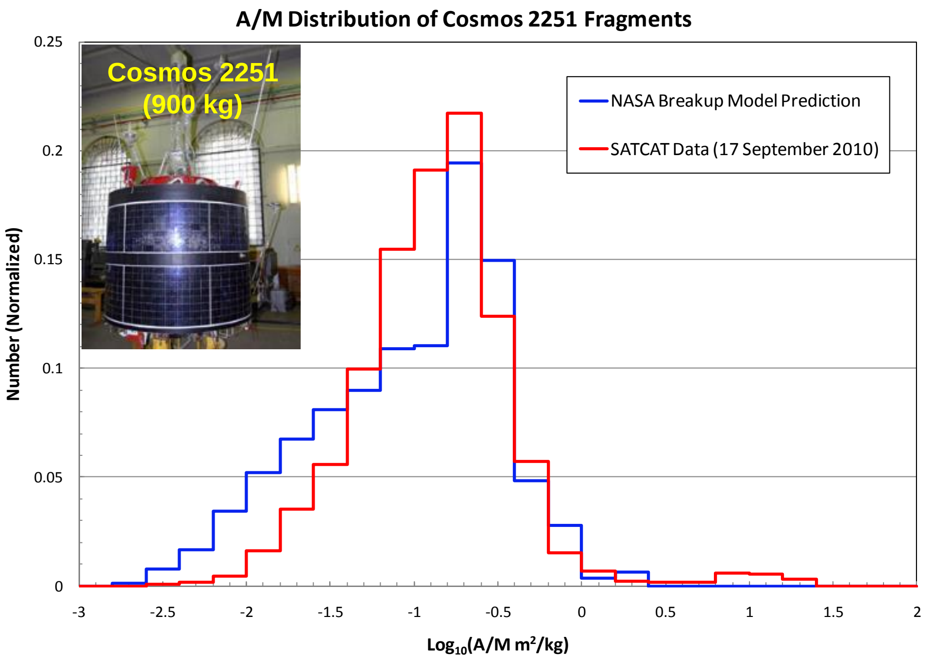
- Outcomes:
  - Database solution used for the data management for DebriSat project.
  - Database solution used for data management for similar “big data” projects.
- Relevance to FAA:
  - Orbital debris modeling is critical to achieving better space traffic management.
  - Archival database using “big data” framework for improved modeling of space debris.

Task Discussion

Orbital Debris Background

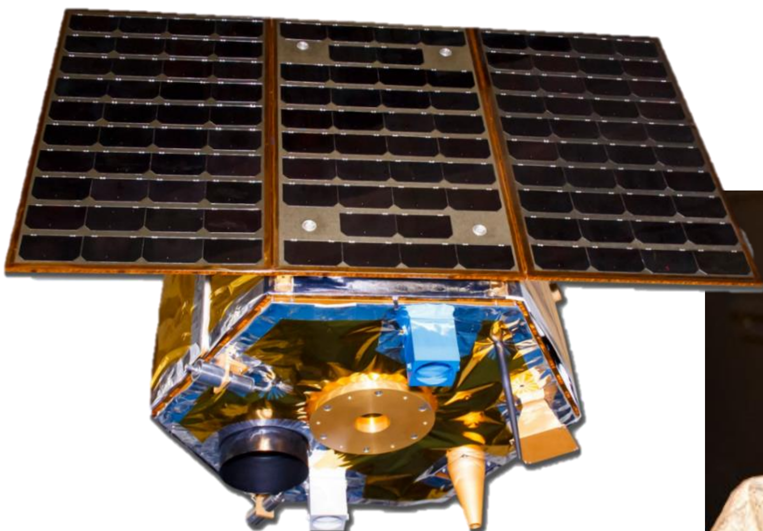
- 23,000+ objects, Iridium 33 – Cosmos 2251 collision was a big contributor.
- Current satellite breakup models based on the SOCIT series of laboratory hyper-velocity impact (HVI) tests.
- Existing models work well for old satellites, less so for newer satellites with modern materials and processes.

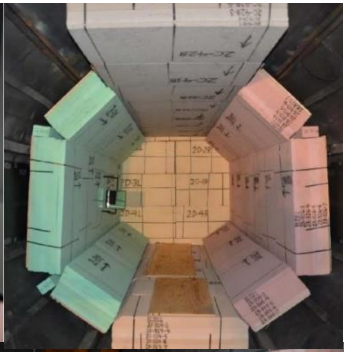




DebriSat Overview

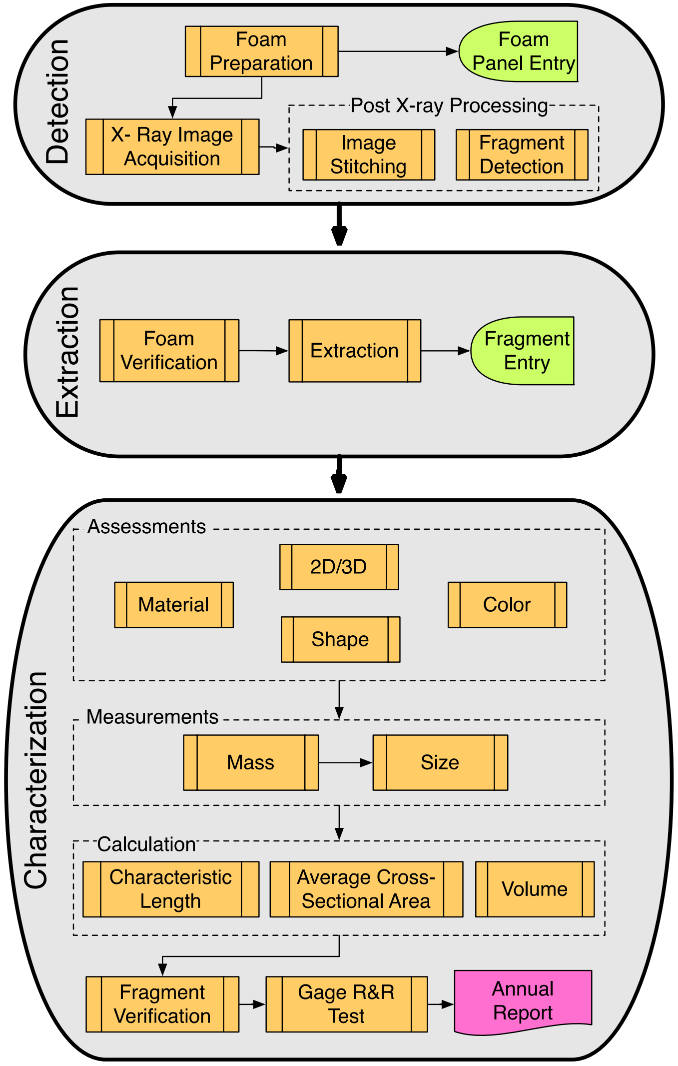
- Test article designed and fabricated as a “representative” modern LEO satellite using modern materials and processes.
- Goal: Update existing satellite breakup models.
- Laboratory HVI test performed in April 2014.
  - 56 kg representative LEO satellite
  - Impact speed of 6.8 m/s (13.2 MJ)





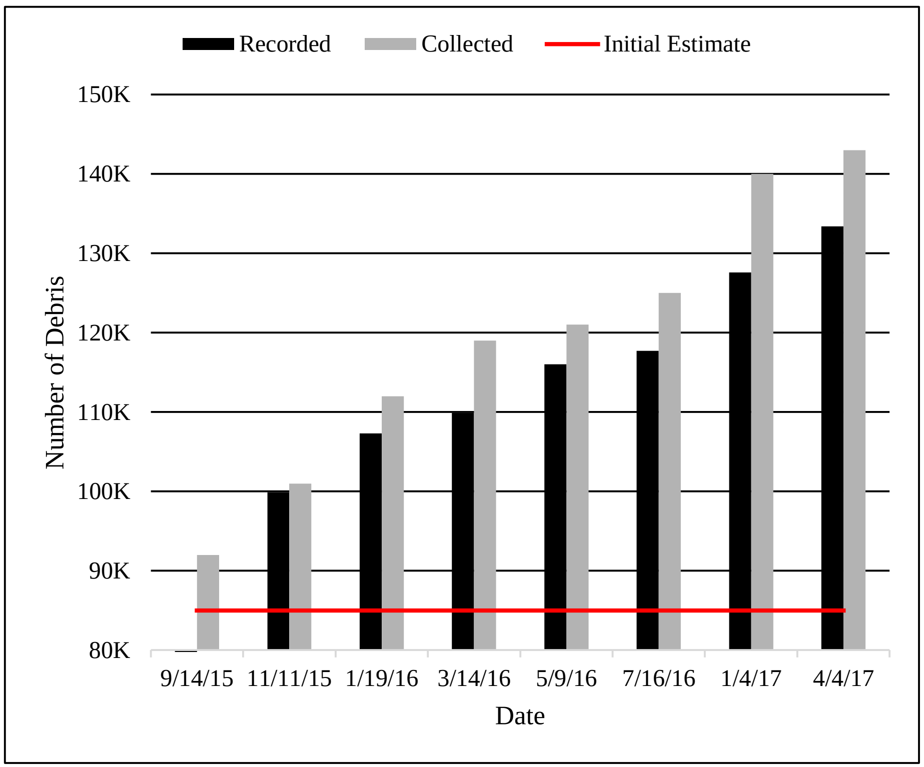
Post-HVI Process

- Fragment Detection:
  - Prepare foam panels for X-ray imaging.
  - Process X-ray images to detect embedded fragments.
- Fragment Extraction:
  - Excavate fragments ≥ 2 mm in one dimension.
- Fragment Characterization:
  - Assess fragment's physical attributes (2D/3D, material, shape, and color).
  - Measure fragment's mass and sizes.
  - Archive all fragment data, images, and associated metadata in database.
  - Verify fragment's database entry.



Data Management Challenge

- Originally expected 85,000 debris fragments.
- Collected and recorded over 200,000 fragments to date (and still counting).
- 300+ data fields utilized for each debris fragment.



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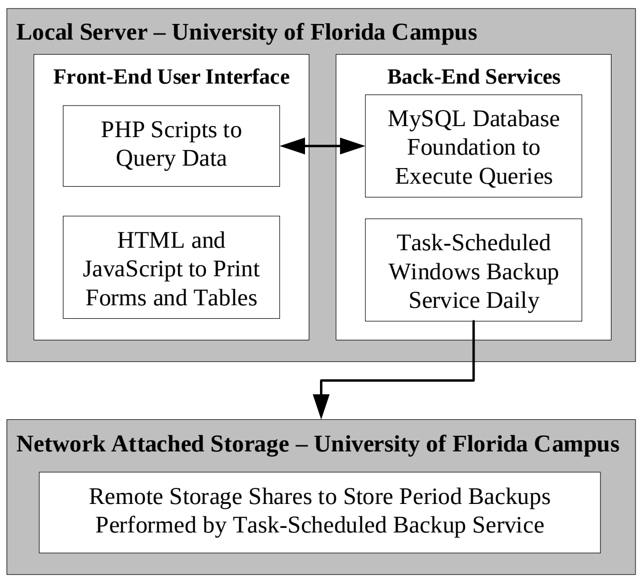
relatedFoam	*balanceType*	*frontlitCapture*
foamId	*balanceSoftwareVersion*	*backlitCapture*
foamType	*imagerType*	…

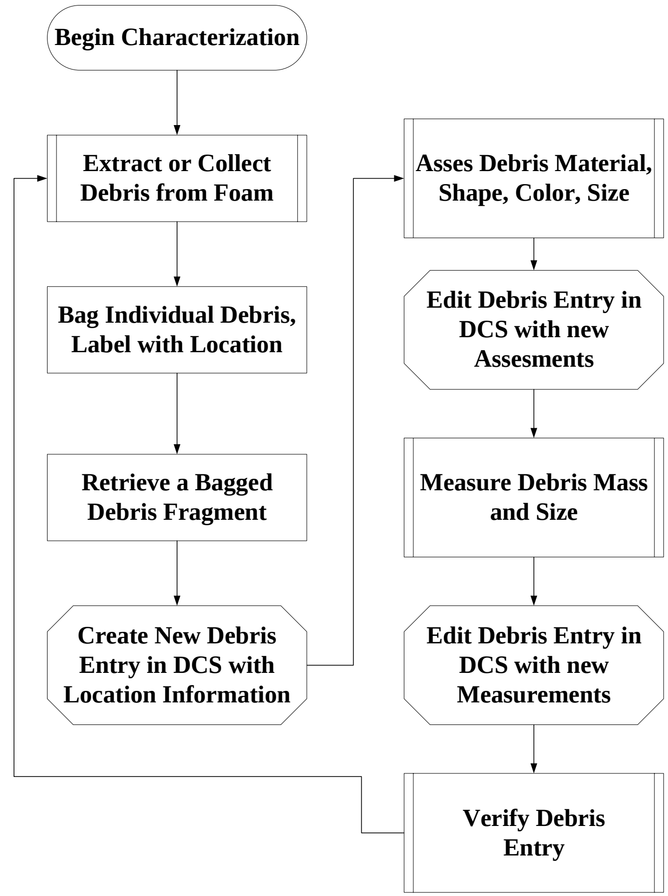
Debris Categorization System

- Requirements:
  - Record data from foam and debris.
  - Guide user through post-impact process.
  - Minimize human error.
  - Maximize user efficiency.
  - Ensure data perpetuity and integrity.

Front-end, back-end dichotomy.

Designed and developed in parallel with the post-HVI phase procedures.



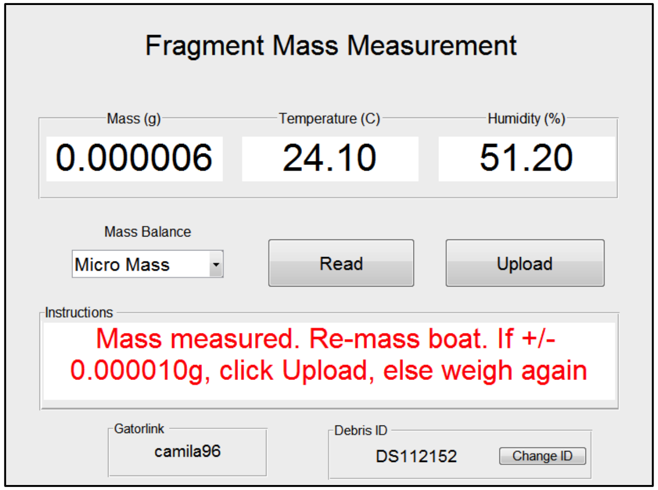


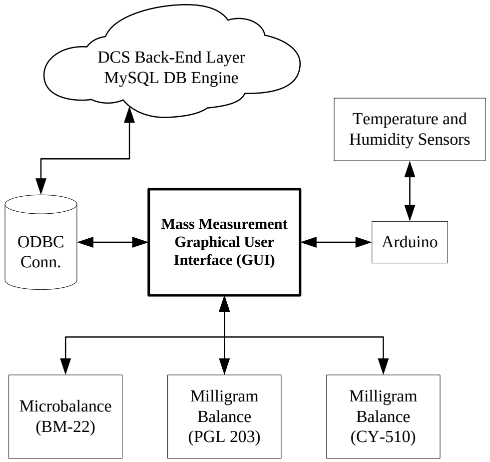
Phases of DCS Implementation

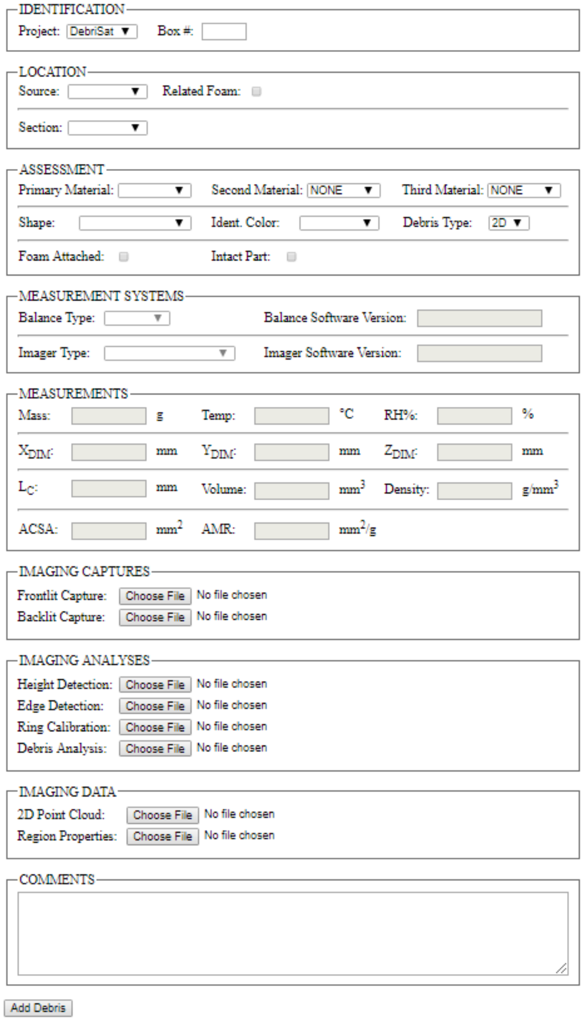
- Two Phases:
  - *Rapid-Development Phase (initial)*
    - Get the system online and operational as fast as possible.
    - Respond to frequent changes in requirements, data fields, etc.
  - *Operations Phase (current)*
    - Ensure all the project requirements are satisfied.
    - Ensure data perpetuity and integrity.
    - Make the system as maintenance-free as possible.
    - Facilitate data transfer to stakeholder organizations.

Rapid-Development Phase

- Simple, convenient, quick design choices made.
  - MySQL database engine used for simplicity.
  - Rich data stored as dynamic links.
- Frequency changes to requirements, data fields and processes mirrored in post-HVI workflow.
- Functional front-end interface and back-end services implemented in 6 months.







Operations Phase

- Primary Goal: Ensure data perpetuity and integrity (i.e. ACID-compliant).
  - ACID (Atomicity, Consistency, Isolation, Durability) used to describe the validity of database engine transactions.
- Indirect storage method for rich data implemented in rapid-development phase posed a risk to data perpetuity and integrity.

	Pros	Cons
Direct Storage	- Guaranteed perpetuity of entire dataset - Increased data integrity - More powerful querying (e.g., get all images of fragments greater than 0.5 g)	- Longer database-wide operations and queries - Decreased performance in some cases - Transfer of full dataset takes longer and requires more attention
Indirect Storage	- Faster access via filesystem - Transfer of full dataset is easier and quicker, requires less attention - Access outside of database	- No guaranteed data perpetuity of dataset - Higher risk, not fully ACID compliant - Less powerful querying (additional steps required)

- Decision (requirements-driven) to implement direct BLOB storage.

BLOB Storage in Industry

- Paper from Microsoft Research in 2006 concluded for files larger than 1 MB, indirect storage was better; for files less than 256 kb, direct storage was better; in between it depends on the application.

  Facebook: Haystack and f4 warm BLOB storage (hybrid)

  Twitter: Blobstore (indirect)

  Azure: BLOB storage provider, different types of BLOBs (hybrid)

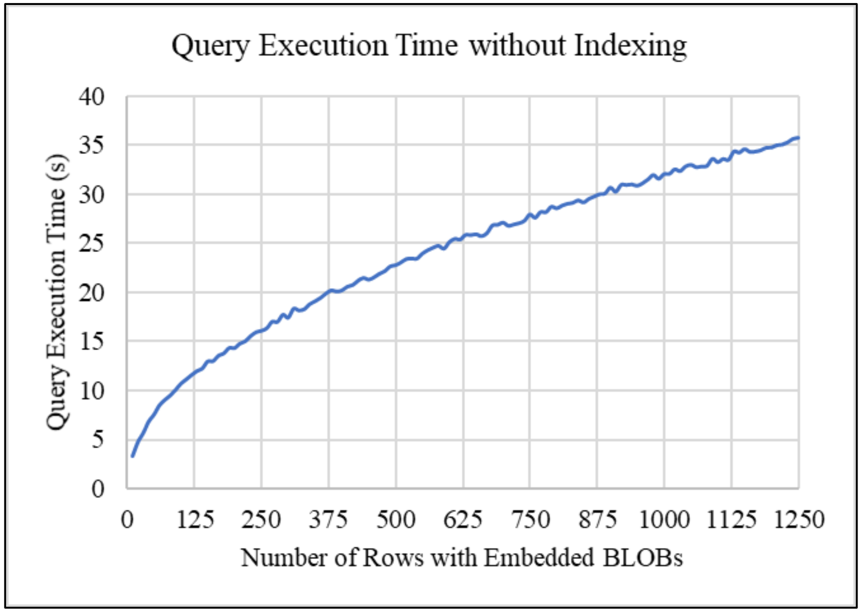
  SharePoint: Storage bins and FILESTREAM (direct)

- Storage method decisions are requirements-driven.
- Almost all of the major companies use custom, hybrid solutions.
- Facebook and Twitter don’t necessarily require data perpetuity.

Performance Concerns

- Direct BLOB storage and incur significant query performance impacts.

- <u>Example</u>:
  - Copied data from between *rapid-development* version to *production* version.
  - Exponential-like query execution time while inserting data.
  - Time to finish copy became prohibitively high.

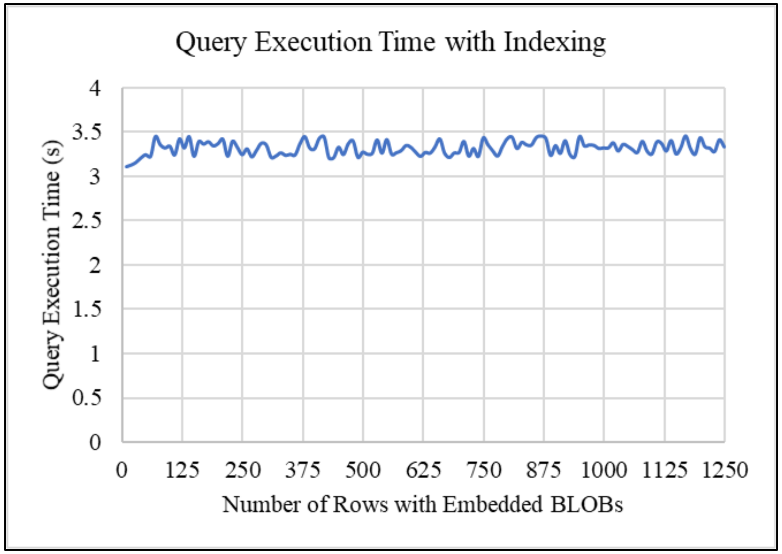


Performance Solutions

- After analyzing the database engine status, noticed a majority of query execution time was consumed by full database-wide scan for rows.
  - Column indexing eliminates full-database scans for queries using indexed columns in their WHERE clauses.
- Front-end user interface could be optimized by writing clever queries leveraging structures like INNER JOIN and avoiding database-wide scans.

Consistently low query execution time for same data transfer example after column indexing.

Use of clever SQL "tricks" can be used to mitigate negative performance impact from direct BLOB storage.



Conclusions and Future Work

- Debris Categorization System (DCS) was designed, developed, and implemented in two distinct stages with different goals.
- Rapid-development phase was necessary because the requirements and structure of the DCS changed frequently and mirrored changes in the physical post-impact phase procedures.
- The goals of the operations phase were primarily to address the shortcomings of quick and convenient design choices in the rapid-development phase.
- Direct BLOB storage was chosen to ensure data perpetuity and integrity per the requirements of the DebriSat project.
- Various SQL “tricks” were employed to mitigate the negative performance impact of direct BLOB storage.