Quantifying Sources of Data Loss for the FORMOSAT-7/COSMIC-2 Mission

Gavin C. James - UCAR, William S. Gullotta - NOAA, Mike Perrotta - UCAR,
John J. Braun - UCAR

UCAR
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Abstract

The FORMOSAT-7/COSMIC-2 (F7C2) mission has a system operational availability requirement of greater than or equal to 91.5% from Full Operational Capability (FOC) to the end of mission duration. In this analysis we identify the primary sources of data loss for F7C2 as the mission approaches FOC. Four specific sources of data loss are considered: 1) loss attributed to spacecraft outage, such as single-event upsets (SEUs) leading to unplanned safe modes, 2) loss attributed to ground station issues that result in the failure of data either being downloaded from the spacecraft or sent to the US Data Processing Center (USDPC) for real-time processing, 3) payload anomalies resulting in loss of instrument data, and 4) loss attributed to data processing center outage such as errors in the processing algorithms within the COSMIC Data Analysis and Archive Center (CDAAC) located at UCAR. Analysis has shown a significant decrease in data loss from mission start compared to the last 6 months of operations. Throughout all phases of mission life, the largest contributor to data loss has been spacecraft-related events. While total loss has decreased over time, the proportion of contribution from each source has remained constant.

This presentation summarizes the methods that have been developed within the USDPC to quantify data loss for each of the four segments of this analysis. All of the above stated data loss sources and future RO missions can benefit from the lessons learned by developing more autonomous ways of validating data management requirements and minimizing loss. We summarize the implications of the loss to the overall mission status and discuss configuration of these tools within CDAAC architecture for the near future. When data loss related to spacecraft lowering is excluded, the F7C2 mission has provided greater than 91.5% data availability.

Methodology

COSMIC-2 has multiple DPC interfaces which are susceptible to failure in data processing or delivery. These are: space assets (spacecraft & payloads), ground antennas, data processing, control, and distribution. The team analyzed all State-of-Health (SOH) data between the time period of 2019-10-01 to 2021-02-28 to identify four primary sources of data loss.

Fig. 1 demonstrates the top-level breakdown of data loss sources as described from the USDPC to be spacecraft-related outages, ground station issues, payload issues & anomalies, and USDPC processing errors. A tool was developed in order to parse through all present and missing SOH data for satellite payloads.

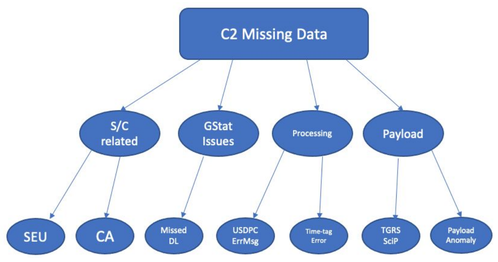

Fig. 1 - Top-down approach for identifying and quantifying C2 data availability

Each payload is designated a specific virtual channel that holds data files that are downloaded from the spacecraft; subdirectories contain SOH files which are used to determine missing files.

- TGRS = VC2
- IVM = VC3
- RFB = VC4
- C2 SOH = VC5

VC5 data is observed for majority of calculations as a reference frame for GPS seconds, as VC5 rarely experiences processing errors throughout mission life (< 0.1%) that either spacecraft issues or ground station issues are accountable. Each category of missing data provides a percentage of absent or failed processing. Spacecraft-related outages are primarily Single-event Upsets (SEU's), or Collision Avoidance (CA) maneuvers that result in powering down payloads. Ground station issues are determined by parsing ΔT between files and coinciding absent files through level1 scheduling files. Queries were ran within USDPC database extracting error messages at each step to delineate payload-specific failures. Utilizing missing data tool to calculate remaining data loss presented a method to designate remaining times to be considered "payload+" describing payload-related issues and anomalies, and all other unaccounted for missing data sources within the remaining category.

Quantifying C2 data loss is ongoing and evolving as more precise tools are developed. The IVM payload-related issues is considered to be an extremely low value as there have been zero reports of IVM anomalies resulting in outages since mission start. The percentages calculated for IVM missing overall in the payload+ subcategory then provides a sufficient error margin for all unaccounted missing data.

Data Loss Sources

- **Total data loss over Mission is 11.54% Excluding Spacecraft Lowering (25774.63 hours out of a possible 223344 hours)**
  - TGRS lost 9193.1 hours (4.12%)
  - IVM lost 8052.65 hours (3.61%)
  - RFB lost 8528.88 hours (3.82%)
- Data loss over first 9 months (2019/10/1-2020/6/30)
  Breakdown of data loss (**total loss=14.33%**)
  - Spacecraft related: 9.21%
  - Ground Station related: .65%
  - DPC related + Payload related: 4.45%
- Data loss over last 8 months (2020/7/1-2021/2/28)
  Breakdown of data loss (**total loss=8.39%**)
  - Spacecraft related: 4.67%
  - Ground Station related: .88%
  - DPC related + Payload related: 2.83%
- **Fig 2.**
  - **section a)** - TGRS missing data; greater majority of payload issues due to occasional science processor errors
  - **section b)** - IVM missing data; more frequent data conversion errors in USDPC processing
  - **section c)** - RFB missing data; FM3 payload anomaly in November 2019 resulting in month loss of data

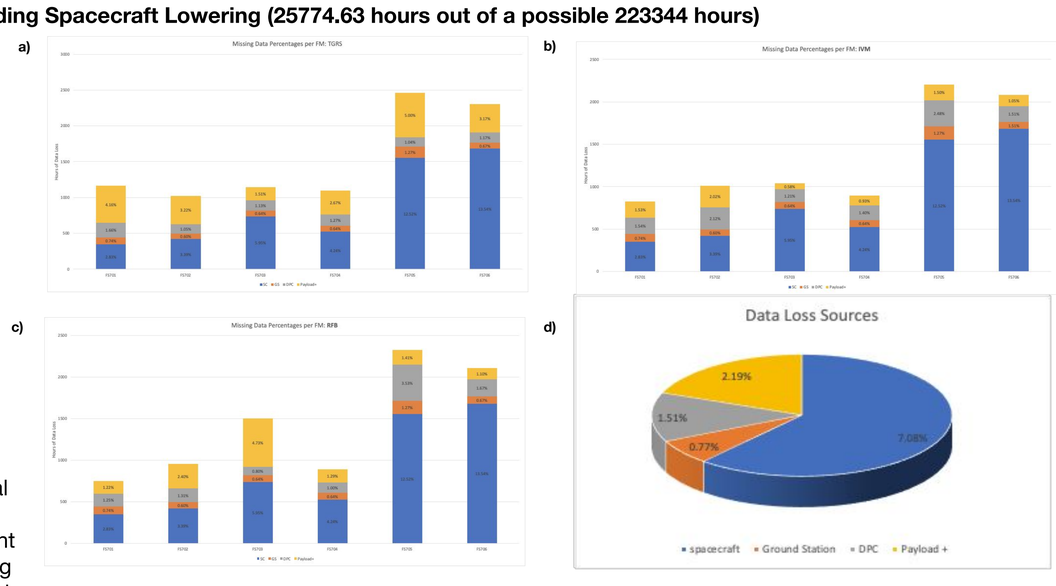

Fig. 2 - Overview of C2 data availability and loss sources, by instrument and then overall impact of each source

During the first 9 months Spacecraft related event contributors, single-event upsets and the "Other", evenly accounted for lost data. The "Other" category included one collision avoidance event during this time period. During the last 8 months, Spacecraft related event contributors shifted such that single-event upsets account for 37.35% of spacecraft related loss, while the "Other" category accounts for 58.3% and collision avoidances for 3.35% of loss. The frequency of collision avoidance events greatly increased since the beginning of 2021.

"Other" category includes events related to data bus, transient wheel, solar array drive, electric module, and AOC.

Fig. 3 shows a decrease in data loss throughout mission life. This is due to less frequent spacecraft related events as well as faster recovery times.

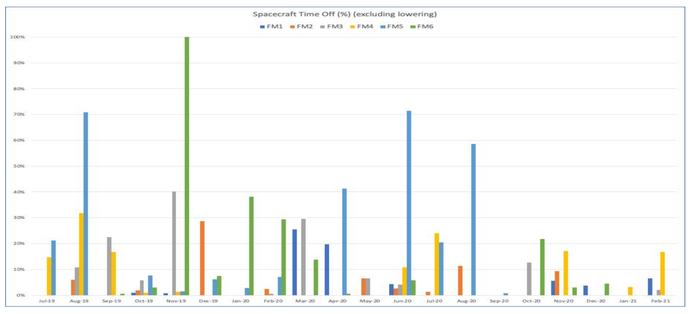

Fig. 3 - Spacecraft outages separated by satellite ID on a month-by-month timeline

- Ground station outages and missed downlinks account for 0.76% of all affected data
  - GS missing data is the least impactful of all data loss, at 6.59% of loss sources (**Fig. 2, section c)**
- **Fig. 4** illustrates the outages by ground station in seconds since 2019-10-01
  - High volume GS outages remain constant through mission life - outages cause upwards of 60 missed scheduled files a day
  - In last 6 months of mission, Ghana produces most frequent missed passes; primary satellite with failed telemetry downlinks are FS705
- Missed downlinks causes are primarily due to SEU's, issue in telemetry download at antenna site, or unexpected failures in file delivery from ground station
  - Excluding spacecraft related issues, total files not present for real-time processing: **906.**

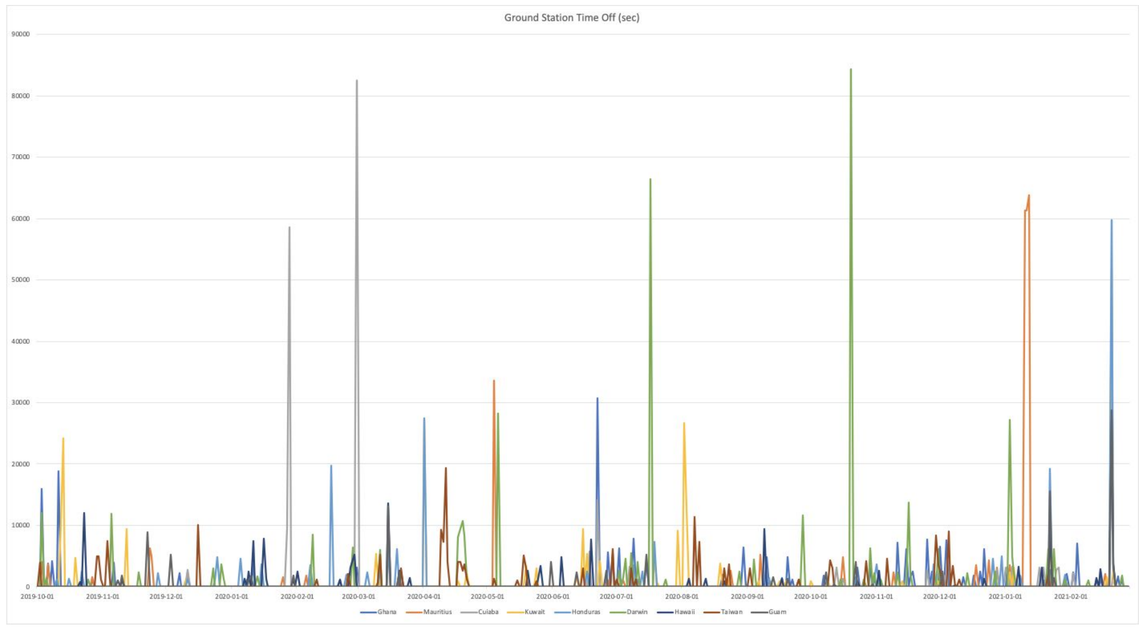

Fig. 4 - Ground Station outages in seconds over mission life.

- USDPC processing errors are identified via database queries isolating failures for each instrument. Error messages regarding payload-specific issues or spacecraft excluded from study.
- 3 different TGRS processing errors are considered, as well as 1 IVM and 1 RFBeacon. These errors occur at steps that fail to produce level1 data files.
- Total number of hours affected by DPC processing errors since 2019-10-01: **3367.49 hours - 1.51%** or all data
- Remaining calculation for missing data counts calculated to be a result of payload anomalies or unaccounted for: **4900.20 hours - 2.19%.**

Impacts of Mission Monitoring

- As of 2019-10-01 there have been a total of **25774.63 hours** of data loss - this consists of 11.54% of all mission data.
- Data loss numbers are skewed by the first 9 months of mission before introduction of more effective USDPC filters in data processing and ground station improvements. Data loss over the last 8 months until present equates to **8.39%** of data affected, within a data availability goal of 91.5%. The UCAR payload team is confident that this will be more indicative of mission performance for remainder of mission life.
- The USDPC and UCAR payload team has actively been mitigating sources of data loss, improving tracking methods and payload monitoring to better isolate and resolve all issues that result in lost telemetry. These actions have produced significant results as are apparent by loss percentages of the most recent 8 months.
- Monitoring tools continue to be developed alongside with NOAA to integrate higher fidelity user interface for CDAAC operations users, and future mission data management goals.

ACKNOWLEDGMENTS

The UCAR payload team would like to acknowledge the UCAR USDPC in their assistance in this analysis, as well as the USAF, NOAA, the NSPO, M4B ground stations, ATLAS ground stations, NASA JPL, and the Taiwan CWB. Special thanks to David Hahn of UCAR, Maggie Sleziak of UCAR, Joe Fong of NSPO, Doug Hunt of UCAR, Jan Weiss of UCAR, and Wei Serafino of NOAA.