Telemetry Mining for Space System

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Agenda

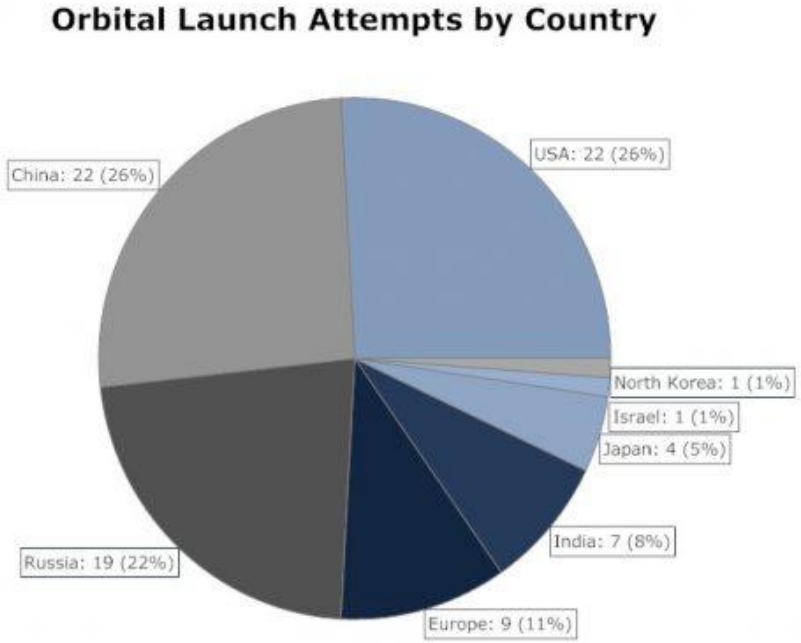
- Introduction
- Importance and Major Challenges for Space Science.
- Telemetry, Tracking and Control (TT&C) Subsystem
- Telemetry Data Mining
- Conclusion

Introduction

- Space technology has become an integral part of our daily lives. Many common everyday services such as weather forecasting, remote sensing, GPS systems, satellite television and communication. **Also**, Space systems have an important role to play in supporting the assessment, early warning, surveillance and response to threats, ranging from natural disasters (earthquakes, tsunamis, geomagnetic storms) to major health risks (pandemics, air pollution).
- Space systems such as artificial satellites, vehicle launchers, space stations, space craft, …etc.

2016 Space Launch Statistics

- The year 2016 saw a total of 85 known orbital launch attempts from space ports in nine different countries. 2016 ranks third in the current century in terms of the total number of orbital launch attempts, short to 92 attempts in 2014 and 87 in 2015.



Death in Space

- The major obstacle to the progress of space exploration and utilization of space for human benefit is the safety.
- Hundreds of people and billions of dollars were lost because of lots of space system failure cases. Between 1959 and 1995 there have been 166 accidents happened in manned space crafts flights out of total 249 (about 67%). As of 2016 saw two failed launches on missions operated by China and Russia.

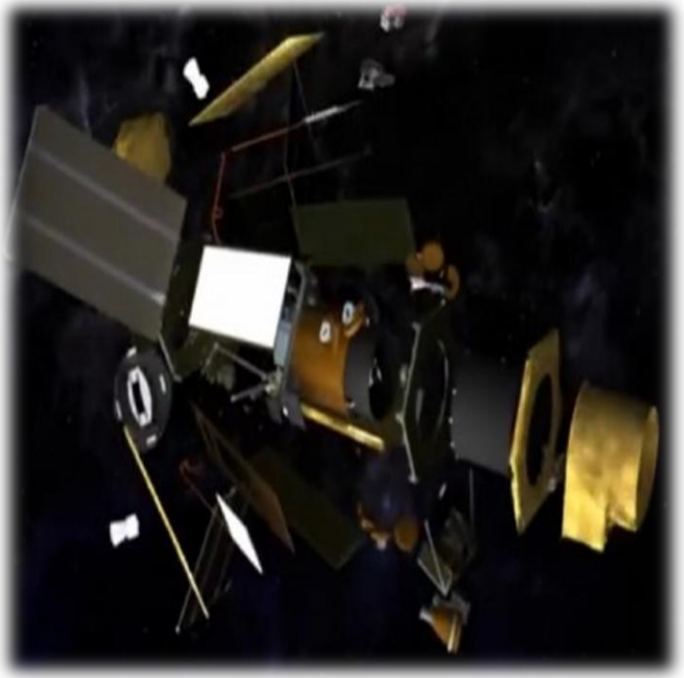
Space Shuttle Challenger disintegrated 73 seconds after its 1986 launch resulting in the death of all seven crew members.

Egypt Sat2

Egyptian Satellite 'Egypt Sat 2' lost

On 23rd April 2015, Russian newspaper reported that Egypt has lost communication with its remote sensing Earth observation satellite EgyptSat 2 on 12th April 2015, less than a year since it was launched in April 2014.

Anatoly Zak, media adviser to the Russian Space Web speaking to Al-Masry Al-Youm, he said that the satellite is almost lost, as experts are unable to modify its path or control its signals. He also commented on remarks by NARSS chief that the satellite's path was observed, saying that the path can be observed but not modified, adding that the expected rate for success to regain control is no more than 15 percent.



Egypt Sat2

The Russian-built Egyptsat-2 satellite was designed to provide high-resolution imagery for the Egyptian military and other civilian government agencies in the country. The satellite is expected to have an operational lifetime of 11 years, the cost approximately US$ 40 million (approx. LE305 million).

On 9th Jan 2017, MOSCOW announced that the Russia's Rocket and Space Corporation (RSC) Energia will produce EgyptSat-A instead of failed EgyptSat-2. Chief Executive Officer of the RCS said that they have already started producing EgyptSat-A at the expense of the insurance coverage for the lost satellite in May 2016, adding: its launch is scheduled in 2019.

Egyptsat-1

EgyptSat 1 (**MisrSat 1**) was Egypt's first Earth remote-sensing satellite. The satellite was jointly built by Egypt's National Authority for Remote Sensing and Space Sciences together with the Yuzhnoye Design Bureau in Ukraine.

EgyptSat 1 was successfully launched on board a Dnepr rocket as part of a multi-satellite payload on 17 April 2007 from Baikonur. Contact with the satellite has been lost on 19 July 2010 due to loss of Control Signal communication.

Egyptian government kept the scientific setback secret for three months, before details leaked out. Egyptian specialists claimed then that this was an experimental project with an expected satellite's service life of no more than three years.

Satellite cluster, including EgyptSat-1 (top left) and SaudiSat-3 (top right) during launch preparations

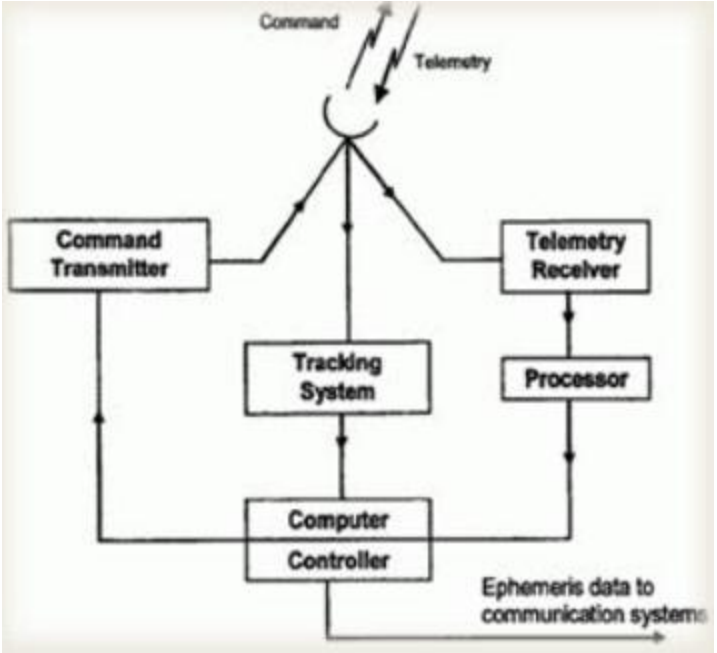
The Challenges

Space systems are amongst todays most complex technical systems, they fulfill their mission in a very special, harsh, and challenging environment. So it is practically impossible to completely eliminate the possibility of anomalies or faults, even if we increase the reliability of the system components to the limit.

In addition to, it is extremely difficult to directly inspect or repair a damaged component of these systems once a severe failure occurs. As well as its paths cant be modified as it has been happened for EgyptSat2.

Telemetry, Tracking and Control (TT&C) Subsystem

The telemetry, tracking, and control (TT&C) subsystem of a satellite provides a connection between the satellite itself and the facilities on the ground. The purpose of the TT&C function is to ensure the satellite performs correctly, the TT&C subsystem is required for all satellites regardless of the application.



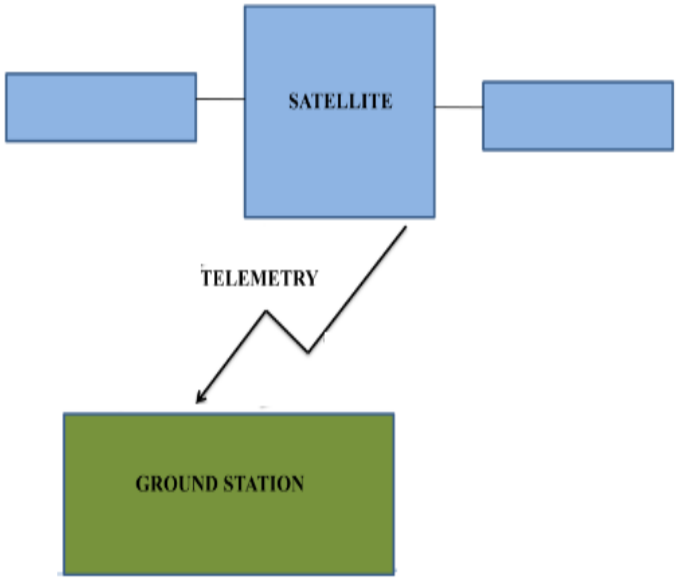
Telemetry, Tracking and Control (TT&C) Subsystem

The three major tasks that the TT&C subsystem performs to ensure the successful operation of an applications satellite:

- The monitoring of the health and status of the satellite through the collection, & processing data from the various satellite subsystems
- The determination of the satellite's exact location through the reception, processing, and transmitting of ranging signals
- the proper control of satellite through the reception, processing, and implementation of commands transmitted from the ground.

Telemetry

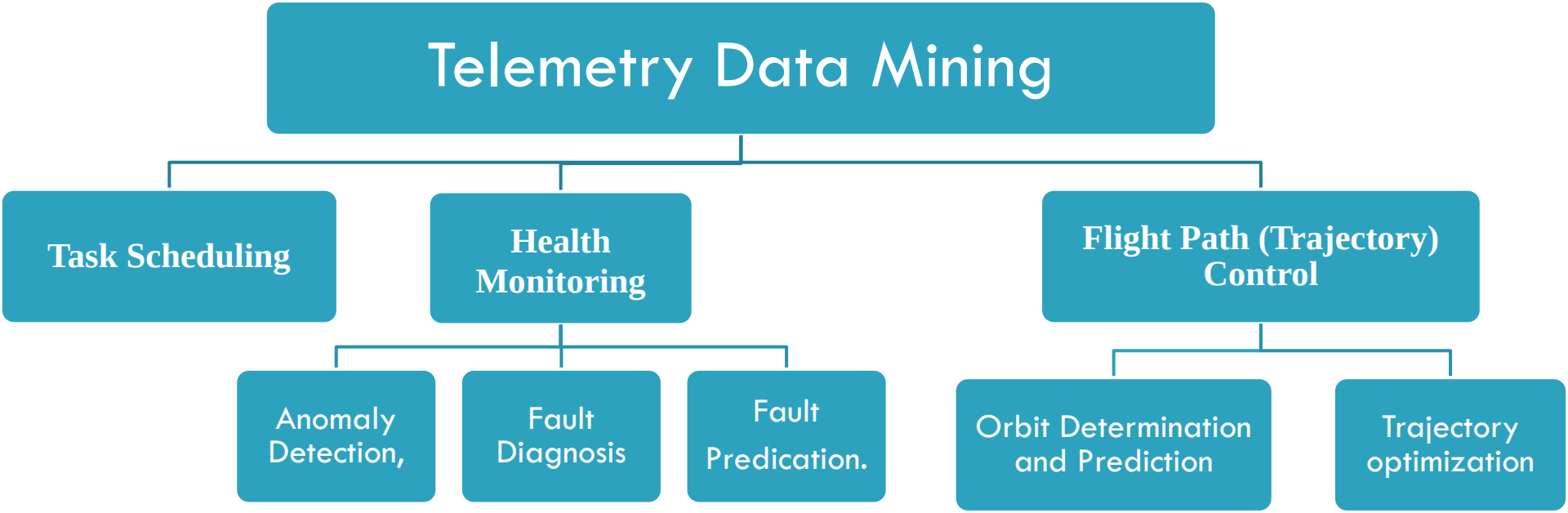
- Telemetry is the link from satellite to ground station, non-stationary time series dataset usually containing thousands of sensor outputs from various subsystems contains a wealth of information about the system and subsystems behaviour, providing health and status updates for the satellite



Telemetry

Measurements related to the health and status of the satellite include:

- The status of resources (e.g., propellant supply and the health and charging status of batteries)
- The attitude of the satellite (e.g., the readings from sun and star trackers or RF tracking systems)
- The mode of operation for each subsystem (e.g., the on/off state of a heater, the direction the antenna is pointed in, or the health and status of imaging systems)
- The health of each subsystem (e.g., output from the solar panels)


Telemetry Data Mining
Task Scheduling
Health Monitoring
Flight Path (Trajectory) Control
Anomaly Detection,
Fault Diagnosis
Fault Predication.
Orbit Determination and Prediction
Trajectory optimization

Health Monitoring based on Telemetry data mining

- **In recent years,** health monitoring based on space systems real telemetry data mining has become the research focus of the field of aerospace. Due to the inherent properties, large size, high complexity and high dimensionality of the telemetry data of space systems, conventional methods are not sufficient for this task, so this calls for efficient data mining techniques for health monitoring applications.
- The major reason for the difficulties in conventional methods (e.g. Limit Checking, Expert Systems And Model-based Diagnosis), they are heavily dependent on a priori knowledge on the system behavior for each space system. Also, there still exist a number of anomalies or their symptoms, which cannot be detected just by monitoring whether sensor values are between upper and lower limits. In other words, some class of anomalies occur without violating the limits on the variables

Health Monitoring based on Telemetry data mining

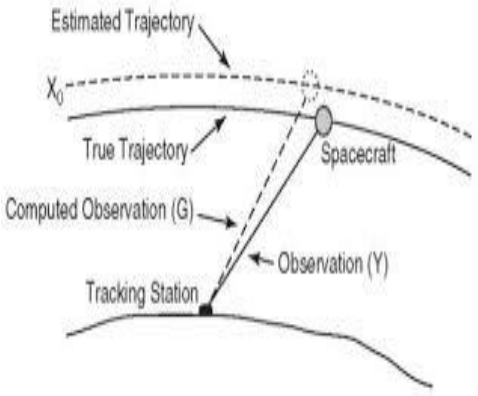
The major tasks of health monitoring for space system:

- **Anomaly detection:** refers to detecting patterns in a given data set that do not conform to expected behavior. The importance of anomaly detection is due to the fact that anomalies in data translate to significant, and often critical, actionable information in a wide variety of application domains.
- **Fault diagnosis and prediction** are the core content and crucial technology for health monitoring of the space systems. Diagnosis is the process of determining and analyzing the fault reason and the impact on the system, and predicting the future trend of space telemetry data is the prerequisite and basis for fault prediction.

Trajectory Mining Space System

Trajectory is often used to describe a portion of an orbit, it is a core technology in the field of space science. Since, there are three main aspects of space system navigation,

- **Orbit Determination**, which is Keeping track of where the space system is currently (orbit determination), and where it will be in the future (orbit prediction).
- **Flight Path Control**, which is evaluating how far the space system has drifted from the reference trajectory, and for designing a maneuver to get the space system back on course.
- **Trajectory optimization**, is the process of finding an optimal trajectory given some set of initial and terminal conditions.



Task scheduling

- Task scheduling of satellite ground station systems is one kind of problem of resource optimization with constraints. In other words, the ground stations and the execution time are assigned to tasks that need to be executed in given time. Until now, this problem has been researched deeply. Usually, these factors are considered. They are time windows, task executing flexibility, and the priority of task. The task success rate and the sum of successful task's priority are taken as the most popular optimization goals.
- Combining of neighbor-area search algorithms and dynamic multi objectives optimization algorithms have been widely used for this problem.

Conclusion

- Space technology have become an integral part of critical infrastructures and key elements for great power,
- Real time Health Monitoring and Tracking are the big challenges for space science,
- Telemetry data mining has become the research focus of the field of aerospace, for health monitoring, tracking and task scheduling.

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