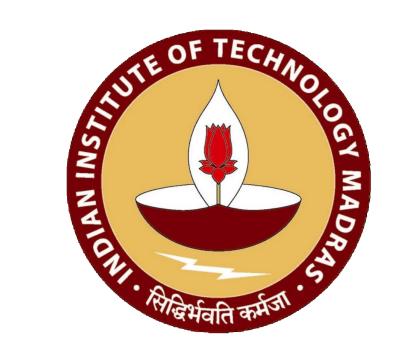
# IITMSAT: Innovative Packet Protocol and Concept of Operations



Akshay Gulati, Sourbh Bhadane, Joseph Samuel, Harishankar Ramachandran, R David Koilpillai



### Vanilla packet protocol — a new standard?

### Motivation

.. AX.25 link layer protocol is a successful standard but it was not designed for Space to Earth links (or vice-versa). Being widely used by radio amateurs, it was easily adopted by the small satellite community.

#### 2. Challenges with AX.25:

- Not designed for communication bandwidth constrained satellites. Long headers (>120 bits) make it sub-optimal for transmission of multiple short frames. Most telecommands designed for small satellite missions can fit within 80 bits (unless TC is used to send files/ upload new code).
- Most COTS radios designed for small satellite missions adhere to AX.25 format only. Implementation of AX.25 on these COTS radios imposes additional constraints on the user (such as frame size, type of CRC).
- There is a need for COTS radios that adhere to a basic packet protocol and gives users ability to customize on top of it.

### Solution

- 1. A fresh approach was carried out to develop optimized TC TM structure.
- 2. Fields are customizable for mission specific designs. Easy to implement in H/W using SDR (software defined radio).
- 3. In a session, a train of frames is sent. A preamble frame first followed by information frames.
- 4. Instead of address/control fields being present in each frame, the preamble frame contains these fields. This frame cannot be standardized as it may be required to add synchronization bytes for phase modulations schemes.
- 5. Information frames have custom fields. Data in these frames is bit-stuffed and frames are separated by flags (0x7E).
- 6. Based on mission requirements, multiple lengths of frames can be designed.

IITMSAT has implemented this protocol in the GS and onboard system without any constraints.

Abstract: IITMSAT is a student-built nanosatellite mission of Indian IIT-M, Chennai, India. The science objective of the project is to understand the nature of precipitation of charged particles (high energy electrons and protons) from the Van-Allen Belts in Low Earth Orbit (600-900 km). The poster focusses on two aspects of IITMSAT design where innovative ideas have been implemented: Packet protocol and ConOps.



| Envelope   | 316 x 326 x 270 mm <sup>3</sup>   |
|--|---|
| Mass   | 12 kg   |
| Power system   | 7 W (consumption) with body<br>mounted solar cells on 4 satellite<br>faces, 4 LiPo batteries  |
| Attitude scheme  | Magnetic field pointing using 3 axis Mag-Gyro and 3 magnetorquer rods   |
| Payload: SPEED (Space based Proton and Electron Energy Detector) | Plastic scintillators, PMTs, WLS fibres, High Voltage (1200V) Range and resolution: Protons: 17 - 100 MeV, 5 MeV Electrons: 1 – 15 MeV,1 MeV Detector Area: 506 cm <sup>2</sup> |
| Antenna  | Inverted F antenna  |
| Downlink (Main)<br>Beacon<br>Uplink                              | 19.2 kbps GMSK 435 MHz<br>40 bps CW 435 MHz<br>1 kbps FSK 145 MHz   |
| Ground Station   | IIT-M Campus  |
| Mission  | 1 year  |
| Launch   | Oct / Nov 2016  |

### Concept of Operations:

### How can these requirements be made easier to use?

- 1. A need to specify operational requirements in a clear comprehensible manner.
- 2. Essentially the question was how they should be defined so that they can be easily verified. Initially the approach taken was to classify all operation scenarios as possible 'states' of the system. However this scheme ended up with the system having so many 'states' that did not convey any intuitive understanding of the system.

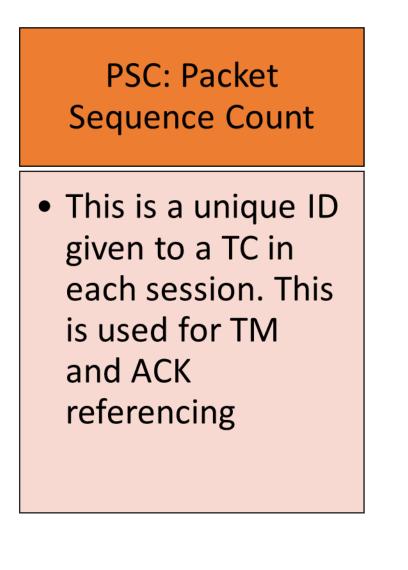
#### Solution

Motivation

- L. ECSS defines 'application process' as a source of TM and a sink for TC. Taking this idea forward, the system is now divided into four application processes. Further each application process was divided into 2-3 'processes' wherein each process can have 2-4 'operational states'.
- 2. Each process has a well-defined flow chart that contain clear indicators (flags/ software variables) whenever a state is changed. This approach has been helpful in describing operational requirements to newcomers, explaining concepts to reviewers, act as a starting point for software developers and aid in generating test scenarios to verify software.
- 3. There are four types of processes. Main, TC based, timer based and supporting processes.
- 4. Processes can be called by each other. During implementation, each step of the process corresponds to a piece of software. However style of implementation can be different from the flowchart.
- 5. A blue step is a simple step but a purple step is another process (that has another flowchart).
- 6. IITMSAT ConOps team has developed more than hundred detailed flowcharts and is being used effectively.

Software and ConOps requirements have been merged into a set of flowchart documents to make it simple and verifiable -> Leads to mission success

## IITMSAT TC TM protocol design (Non — AX.25)



Field

One TC packet in one frame.

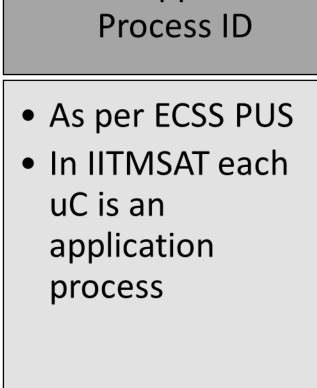
tion standard (PUS).

cation process.

processes.

vice).

Two TC lengths (Long/ Short).



TC PSC

TC Packets design overview

Packet structure based on ECSS Packet Utiliza-

Application process: There are three microcon-

Application processes are further divided into

FMS (Function Management Service).

MMS (Memory Management Service).

OBSRS (Onboard storage and retrieval service)

OBOSC (Onboard operations scheduling ser-

PMS (Payload Management Service): Time

tagged TCs to change science mode

tination amateur radio call signs.

TVS (Telecommand Verification Service).

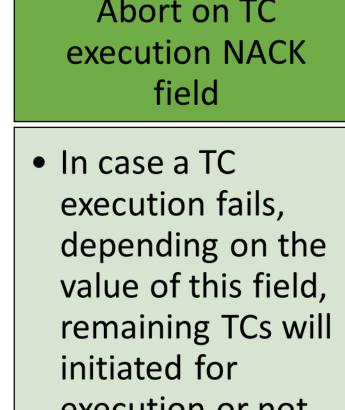
# **APID: Application**

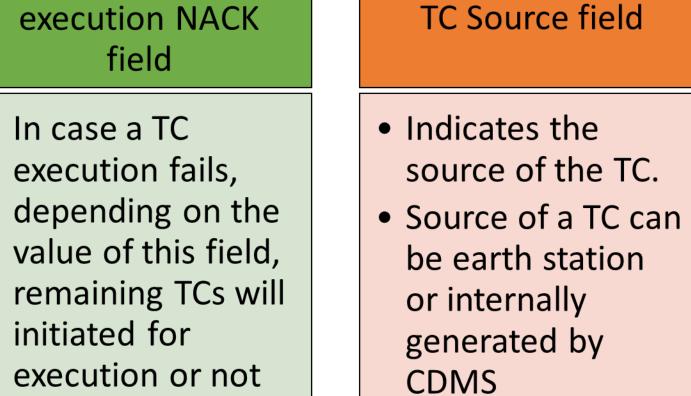
#### Indicates whether the current packet is the last in the series of TCs transmitted

LAST TC

Last TC field

### Specifies the data size of the TC. • IITMSAT has 2 lengths of TC • Short: (11 Bytes) and Long (125





IITMSAT TC packet protocol

SPARE

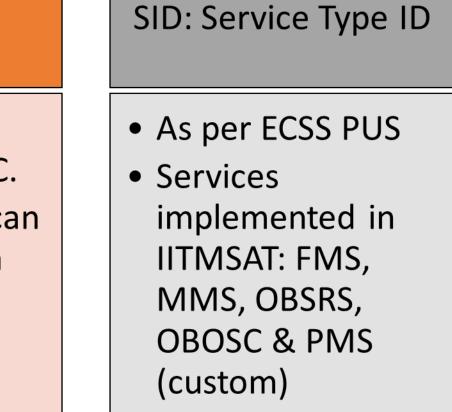
different types of

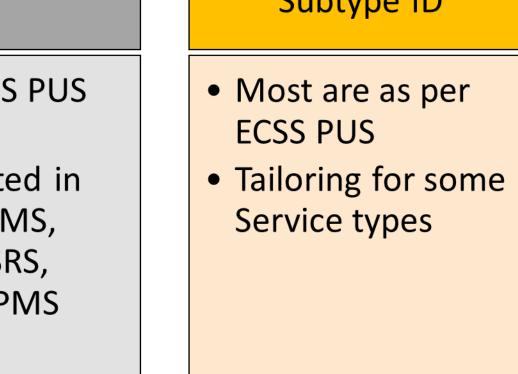
data for GS sorting

**HK and Science** 

and display

Bits





Packet Data Field

SSID: Service

APP. DATA

### All the details of the TC are specified in this

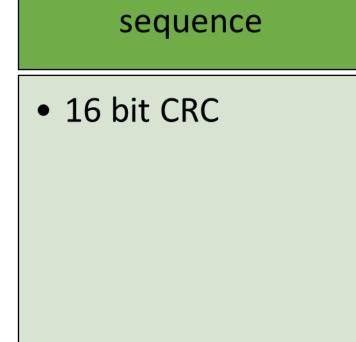
**Application Data** 

PCS

CRC

• TM type:

FMS



**Total** 

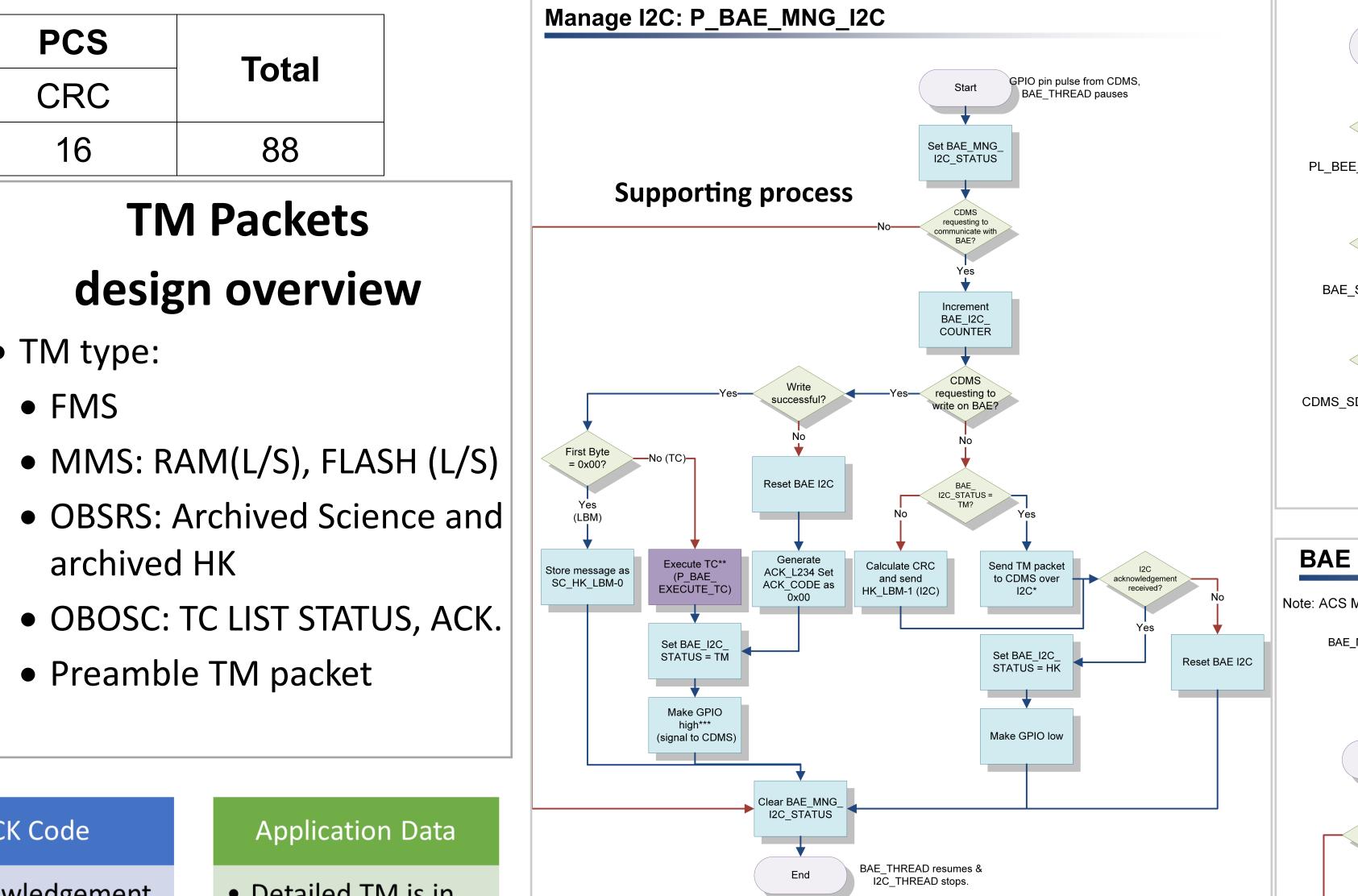
**TM Packets** 

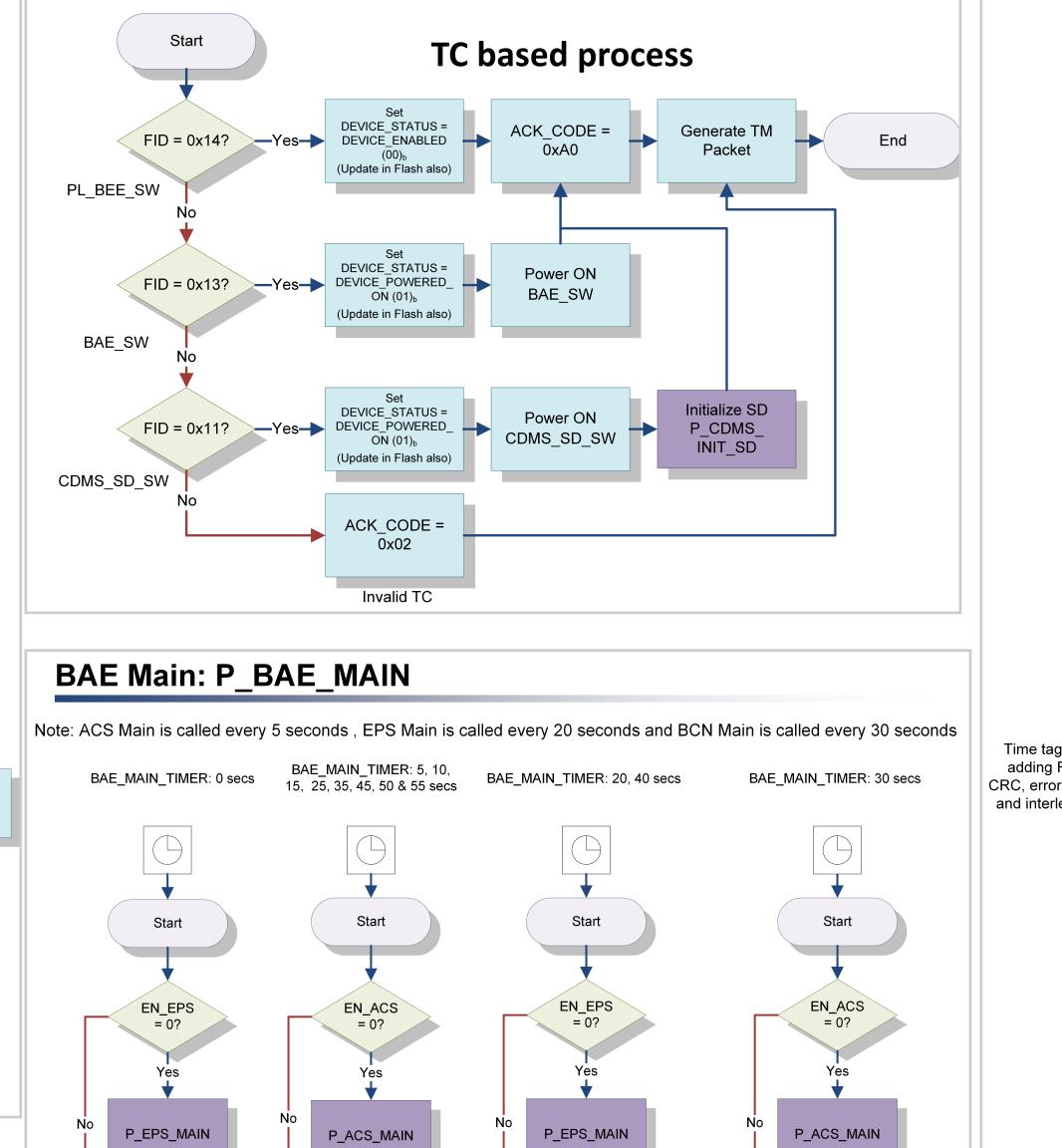
design overview

**PCS Packet Check** 

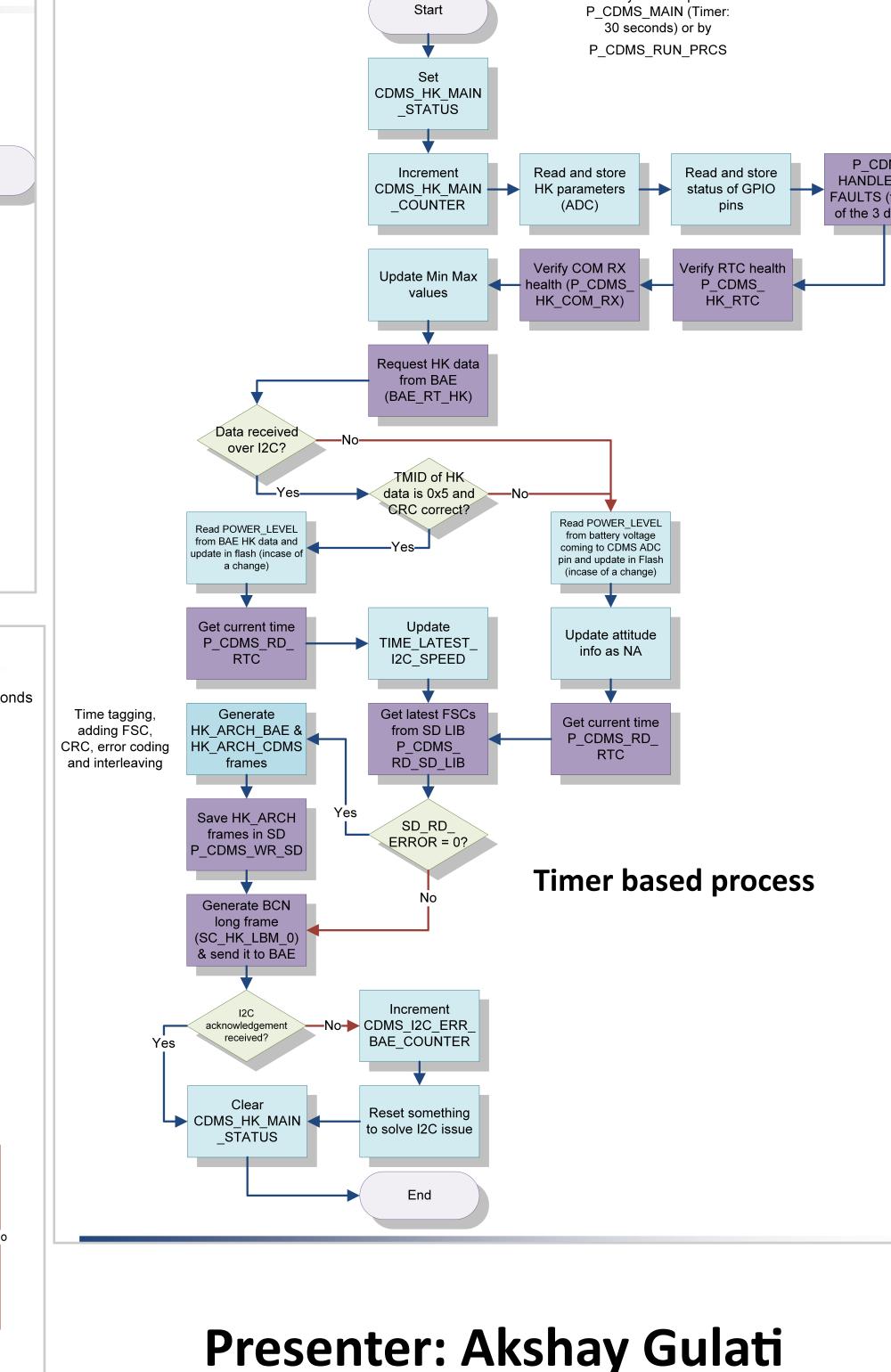
### IITMSAT ConOps flowcharts

FMS TC: F\_CDMS\_SWCH\_PWR\_ON (FID: 0x1\_)





Main process



Housekeeping Main: P\_CDMS\_HK\_MAIN

Process with (ECSS Services)

ACS: Attitude Control System (FMS, MMS)

EPS: Electrical Power System (MMS)

BAE Main (FMS, MMS)

BCN: Beacon (MMS)

PL Main (PMS)

• In IITMSAT, there

are two TM data

TC SOURCE

**Application** 

**Process** 

CDMS-

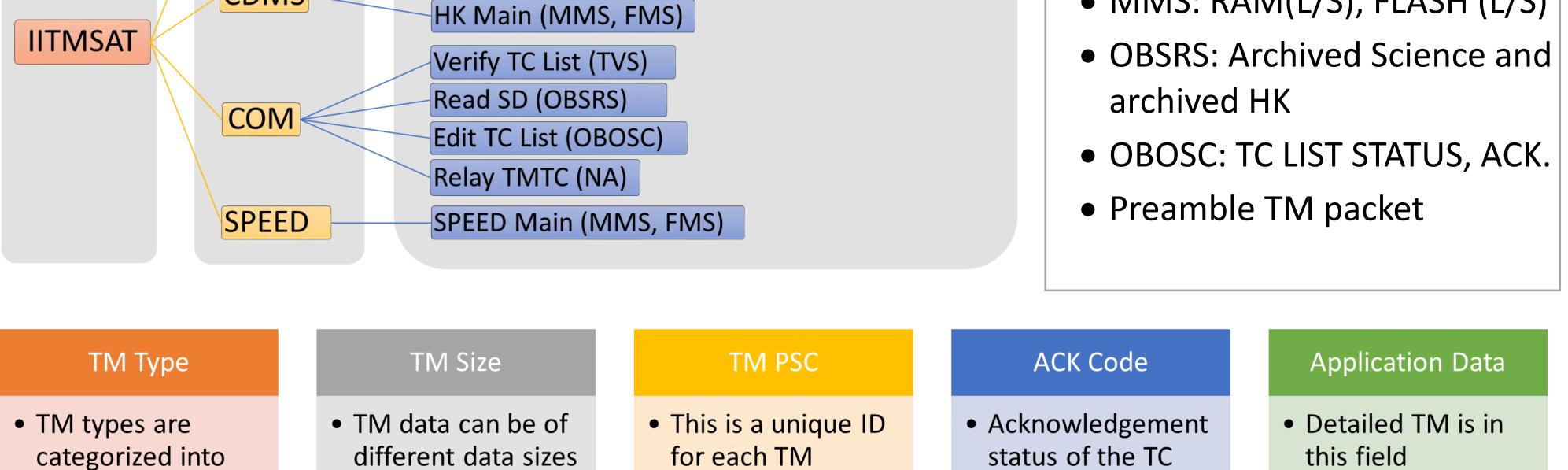
### Designed for Half-Duplex communication.

- trollers (uC) in the satellite. Each uC is an applilist are received correctly by satellite.
  - All TM packets are tagged by TC PSC
- (except OBSRS TM, tagged by SD block no). ◆ A process is a sink for a TC and a source of TM.
   ◆ OBSRS TCs are designed to access each ECSS services (TC type) implemented in IITMSAT:
  - and archived housekeeping data. Not possible to request for retransmission
  - Status of all TCs and TC List sent after exe-
  - All TCs executed in order of PSC (except
- Preamble TC packet: Contains source and deslist (Retry TC execution, disable TC and re-

### Communication ConOps philosophy

**Packet Header** 

- A TC list approach (multiple TCs) for each session. Possible to have multiple sessions
- TC execution begins when all TCs in the TC
- block in SD directly and retrieve science
- of TM. Need to resend TC in case of incorrect TM.
- cution of each TC.
- OBOSC).
- OBOSC TCs are TCs to designed to edit TC set session).



for each TM packet of a TC Used to keep track of number of TM packets

• As per ECSS PUS

 Detailed TM is in this field

Application Data

1072

16

IITMSAT TM packet protocol **PCS** Packet Data Field Packet Header TM PSC | ACK. CODE | APP. DATA

Presenter: Akshay Gulati akshaygulati26@gmail.com +91 99520 92819