TNO innovation for life

SATELLITE LICENSE PLATE

A cooperative laser-enabled satellite identification method

2022 Clean Space Industry Days | 12 October 2022
ESA ESTEC
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SPACE SITUATIONAL AWARENESS
OPTICAL TECHNOLOGIES

- Earth orbit is populated by numerous space objects (operational satellites or space debris)
- Some countries (e.g. the US) are preparing for a national STM regulation. EU will follow.
- EU has ambitions to improve STM capabilities.
- Importance of being able to identify the satellite also when not operative
- Optical technologies have several advantages e.g.:
  - Could be an added functionality to optical communications infrastructure (no need of new ground infrastructure)
  - Better angular resolution vs size of the infrastructure
  - No RF interference/license limitations

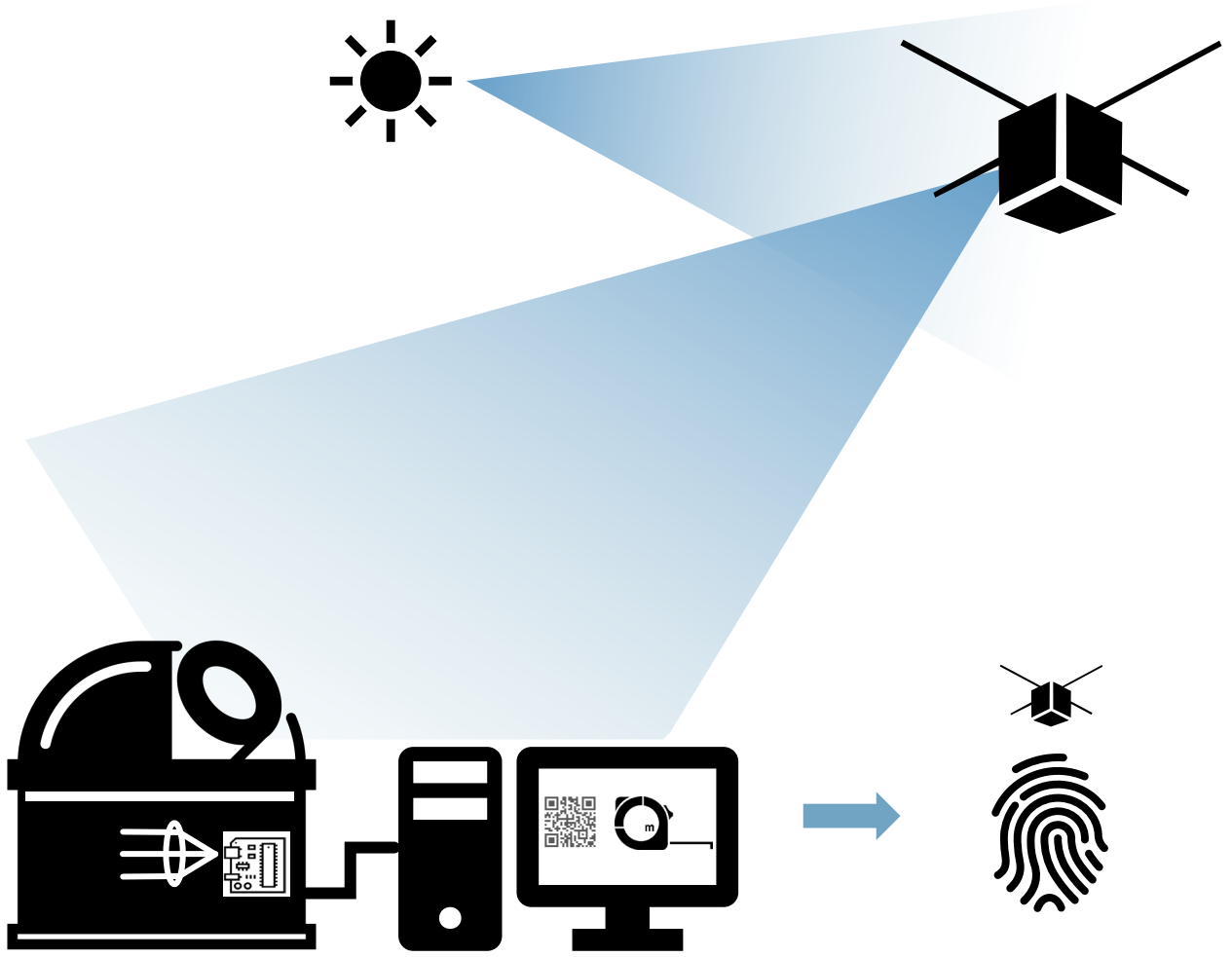
NON-COOPERATIVE IDENTIFICATION

Modelling:

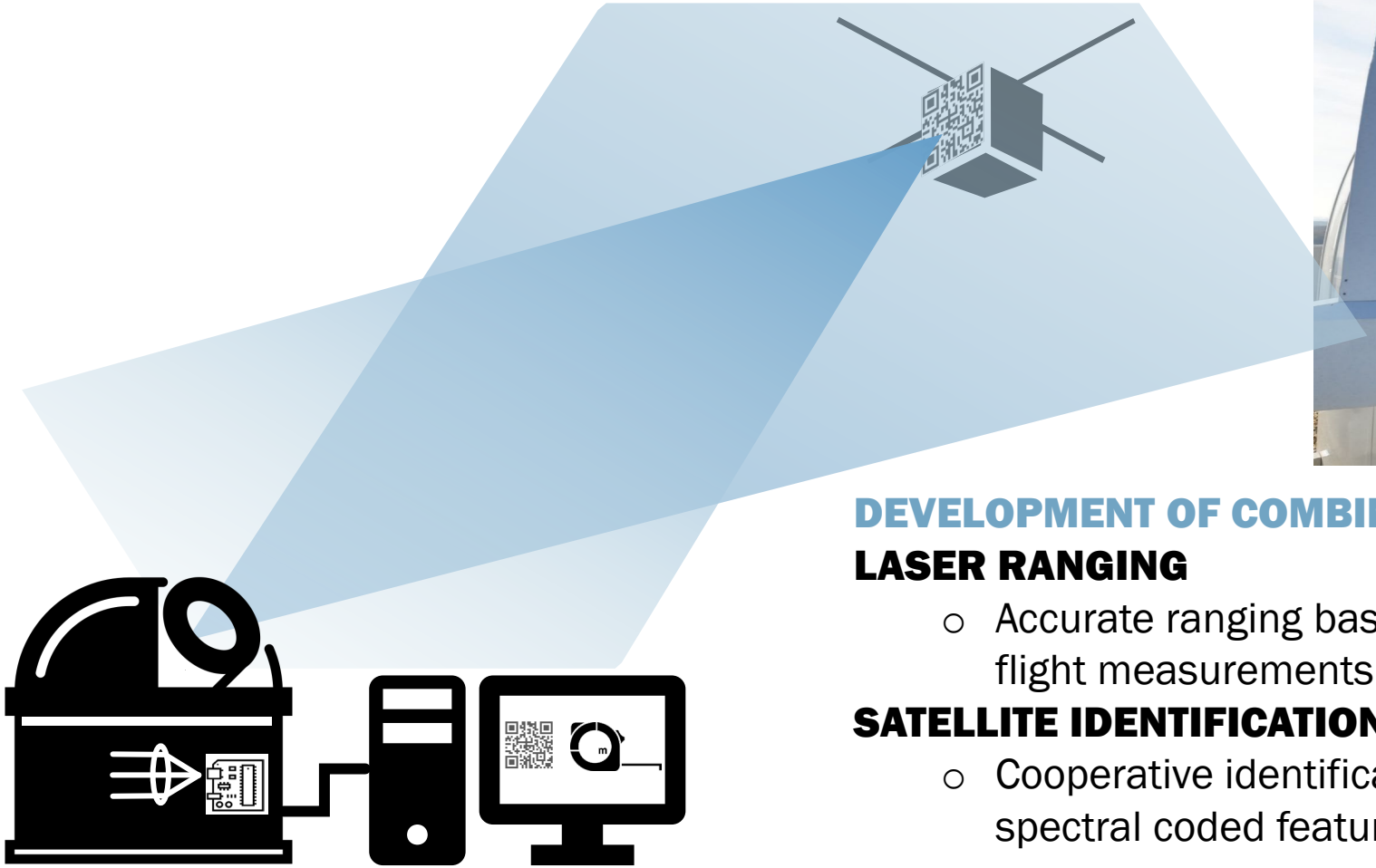
- Development of a model of reflected light from satellites in the spectro-polarimetric domain
- Validation of models with tests with telescope in Den Haag

Tests:

- **Collaboration with Leiden University and TUDelft:** Spectropolarimeter for SSA



LASER RANGING AND COOPERATIVE SATELLITE IDENTIFICATION



DEVELOPMENT OF COMBINED OPTICAL GROUND STATION

LASER RANGING

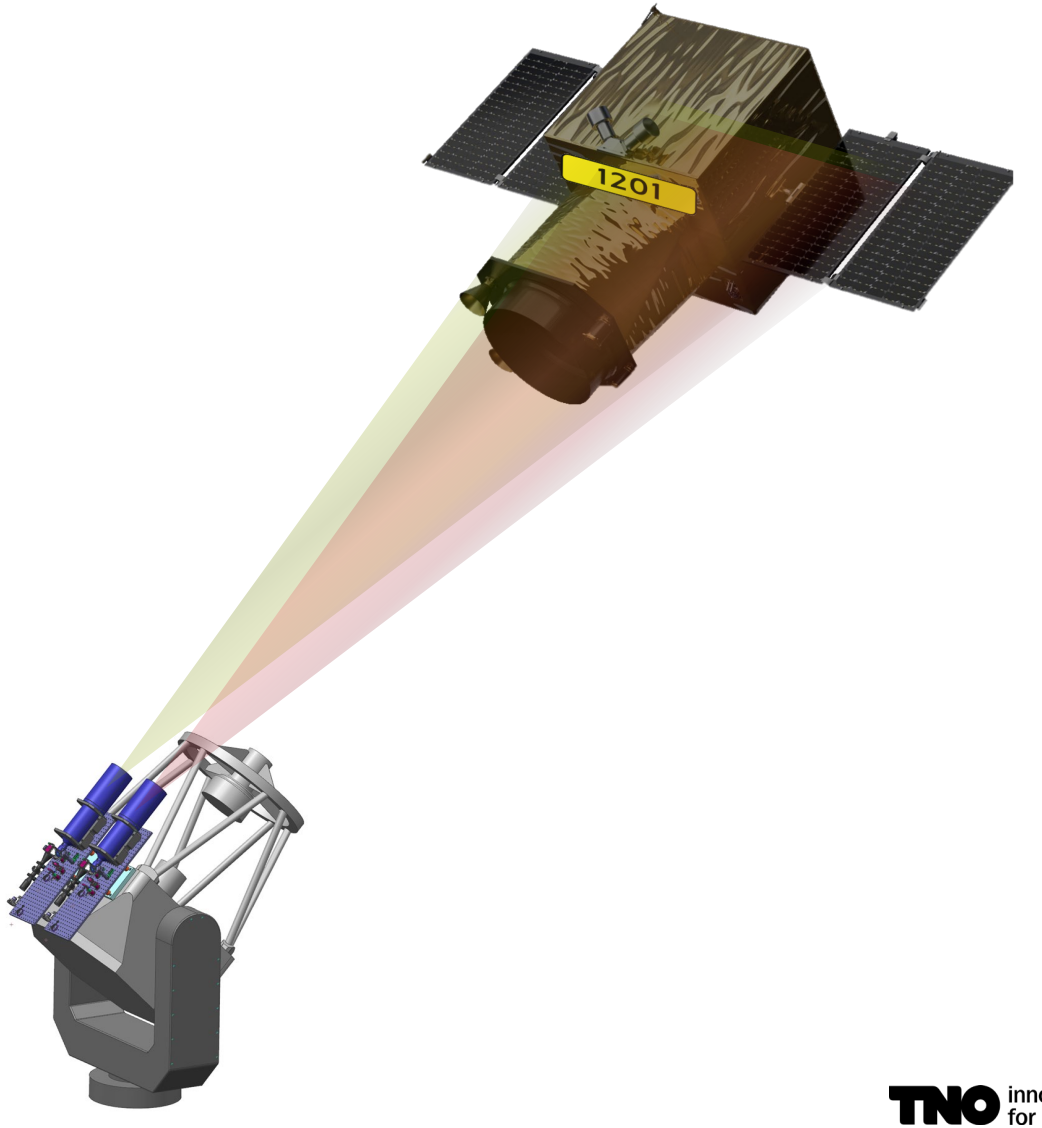
- Accurate ranging based on laser pulses based time of flight measurements

SATELLITE IDENTIFICATION

- Cooperative identification of satellite based on spectral coded features (e.g. spectral QR code)

AUTOMATIC NUMBER-PLATE RECOGNITION
FROM GROUND TO SPACE

Source: Omnitec group



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SLP IN A NUTSHELL

- COOPERATIVE IDENTIFICATION
- PASSIVE TAG SYSTEM ONBOARD
- USES EXISTING OPTICAL COMMS INFRASTRUCTURE
- ACTIVE IDENTIFICATION AFTER SEPARATION
- WORKS ALSO AFTER END OF LIFE

OPTICAL GROUND STATION

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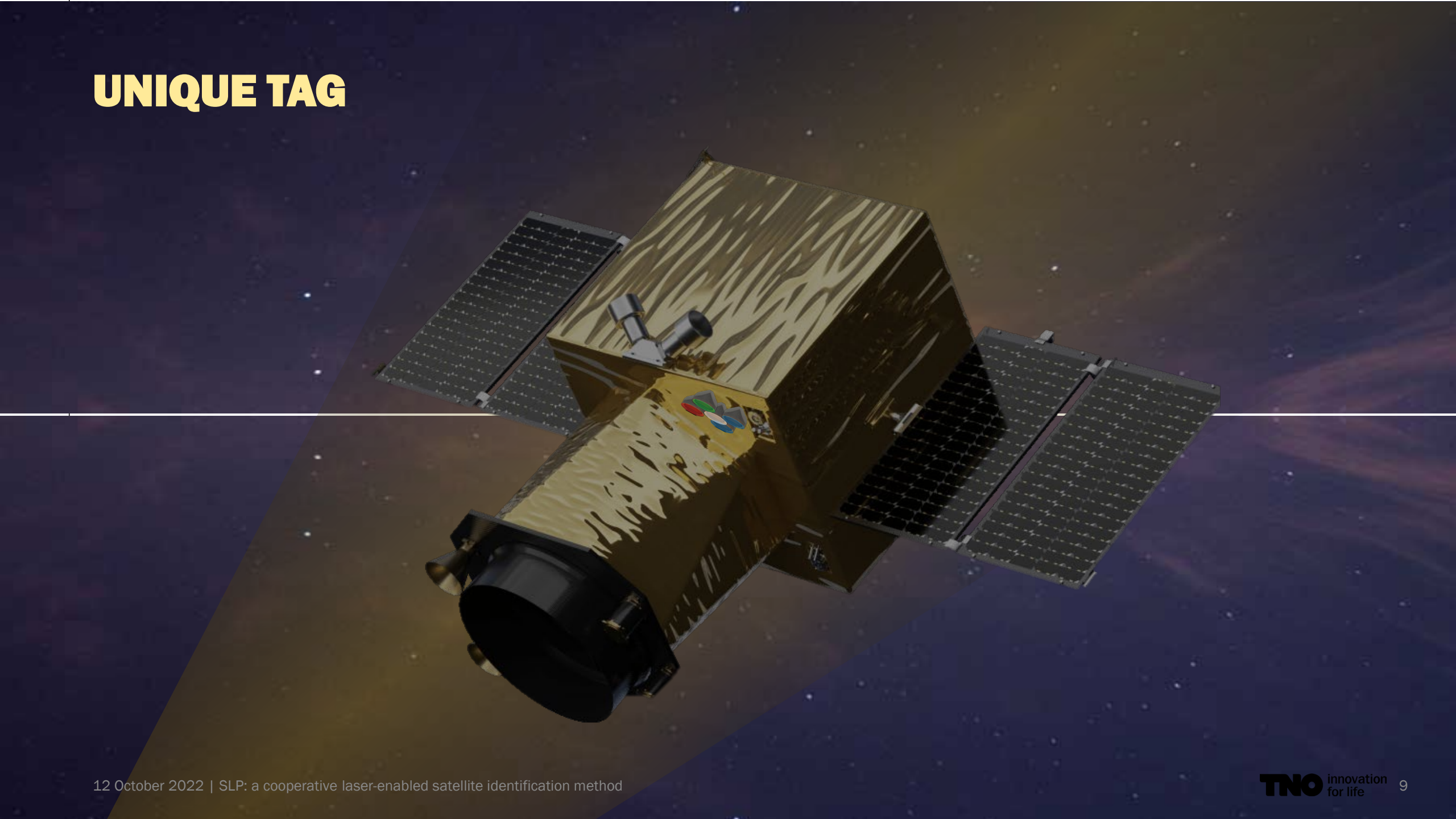
- SATELLITE TRACKING
- PULSE TRANSMITTER
- LARGE APERTURE RECEIVER
- IDENTIFICATION ELECTRONICS
- LASER RANGING


TNO

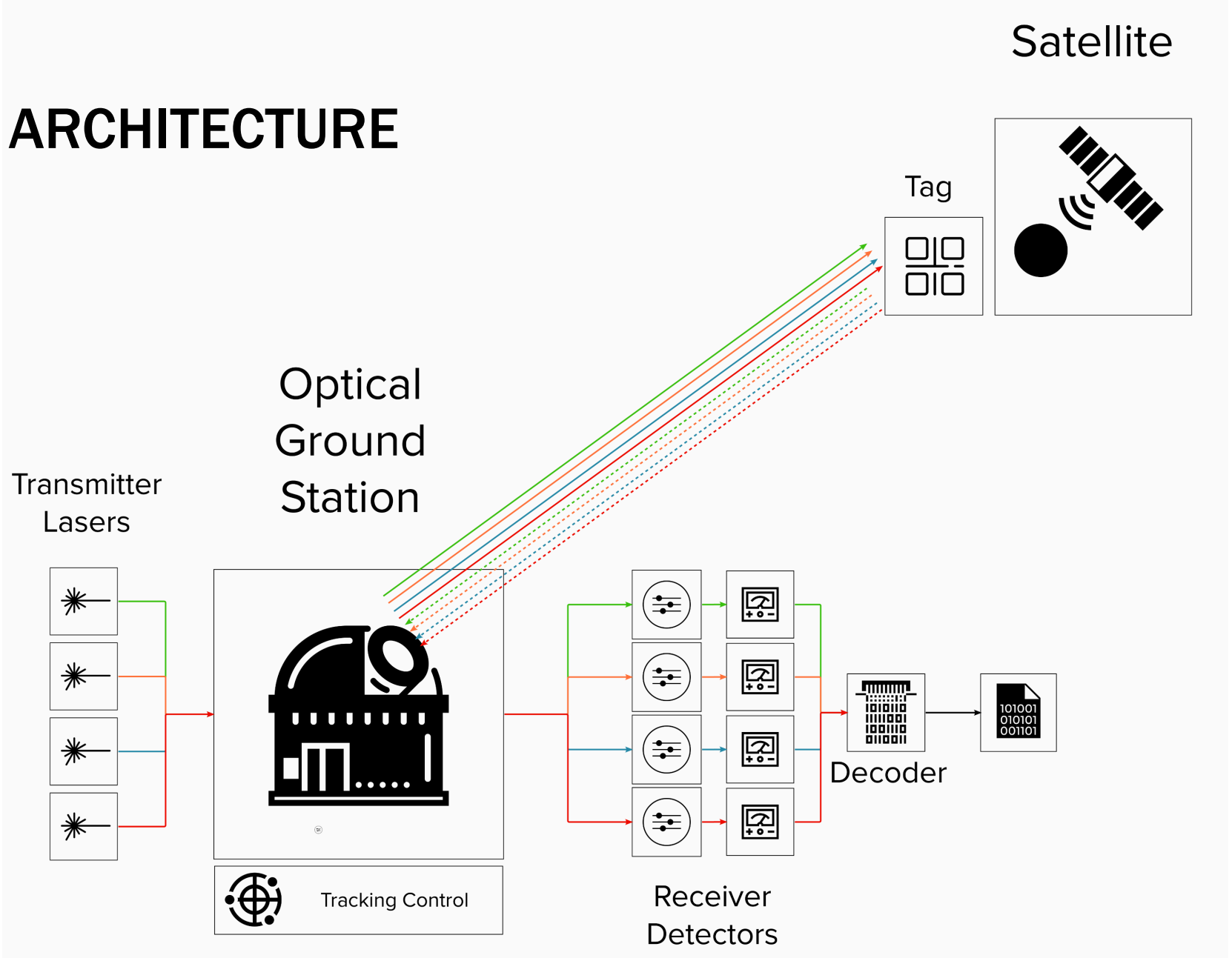
UNIQUE TAG



UNIQUE TAG

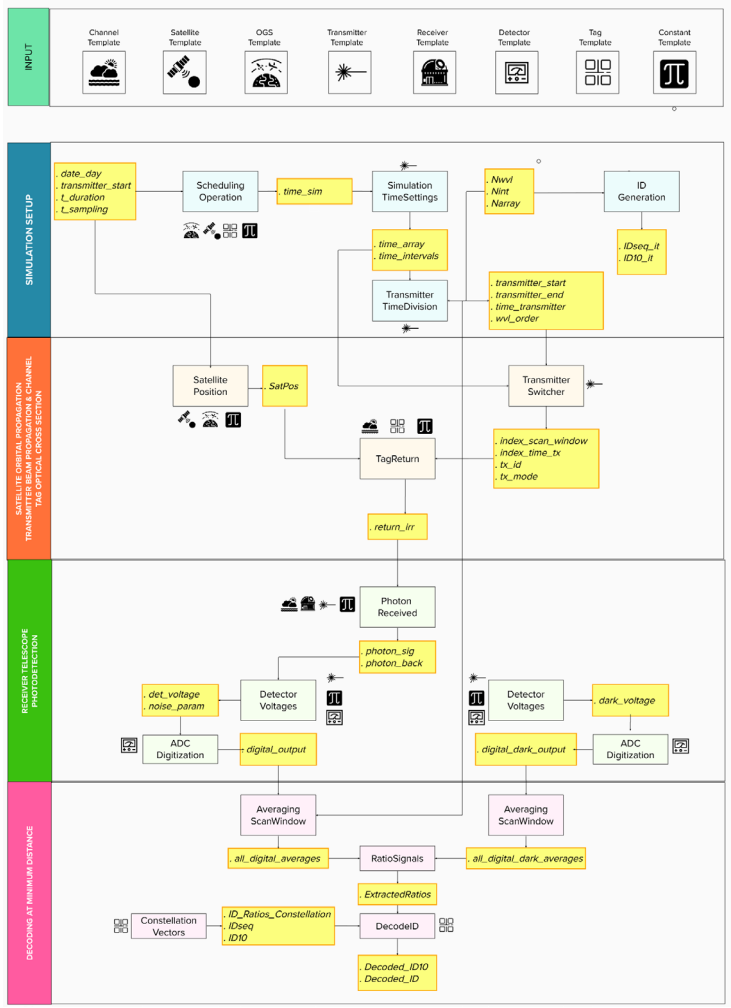
- UNIQUE SPECTRAL SIGNATURE
- DUAL USE: IDENTIFICATION AND RANGING
- MINIMALLY INVASIVE VOLUME
- PASSIVE
- 35 TAGS UP TO > 200

SLP
SYSTEM ARCHITECTURE

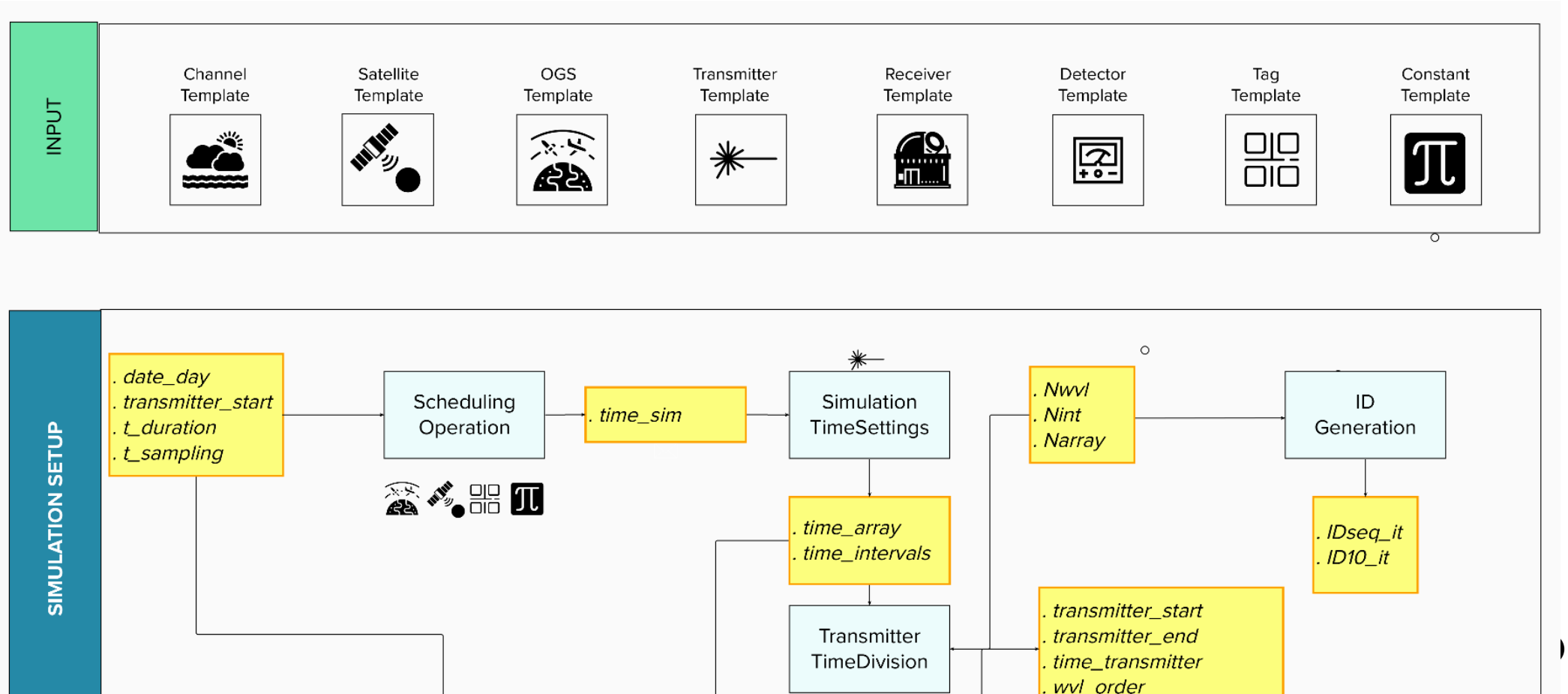


SLP END-TO-END MODEL

MODEL FLOWCHART



SLP END-TO-END MODEL
SYSTEM ARCHITECTURE



SI
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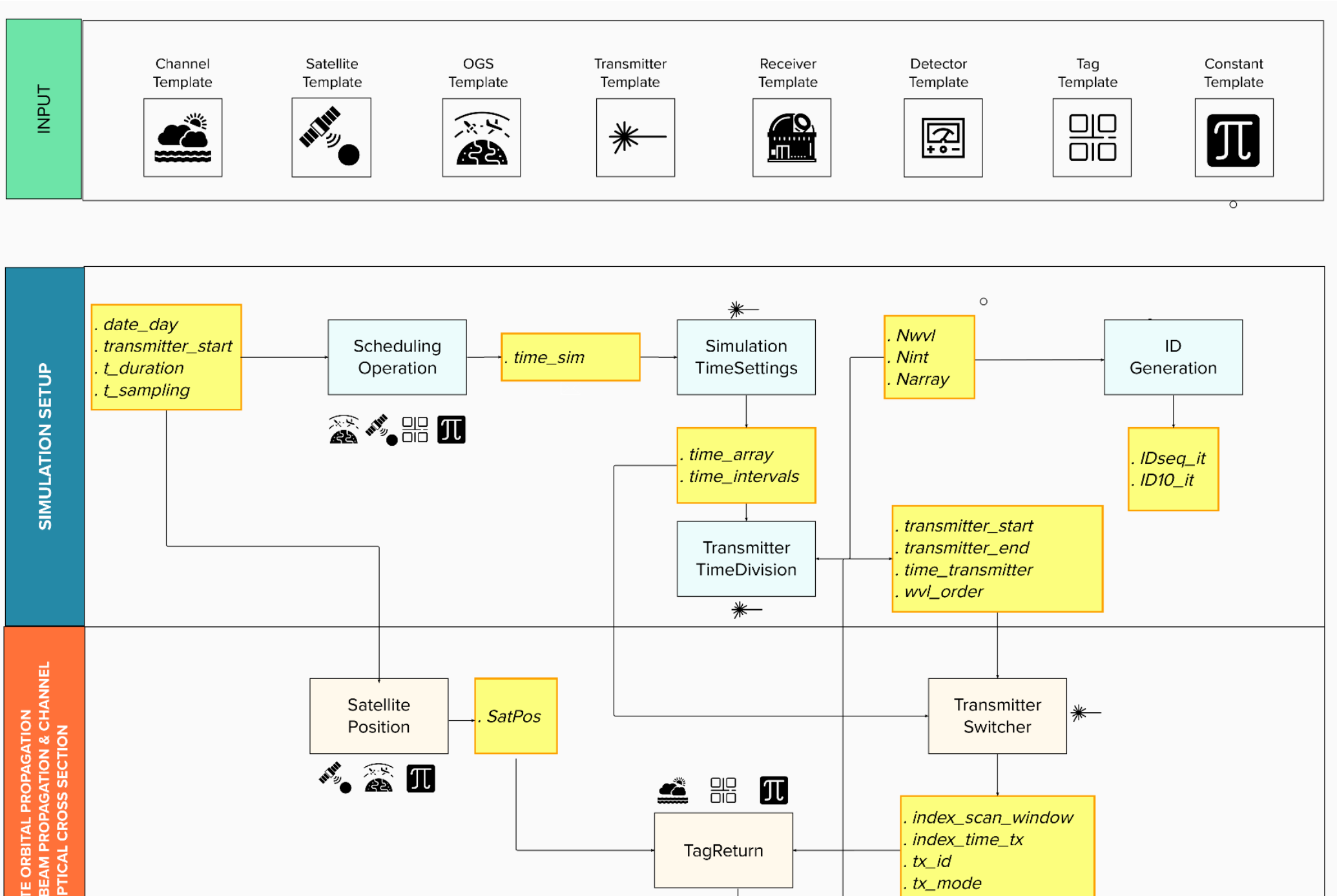
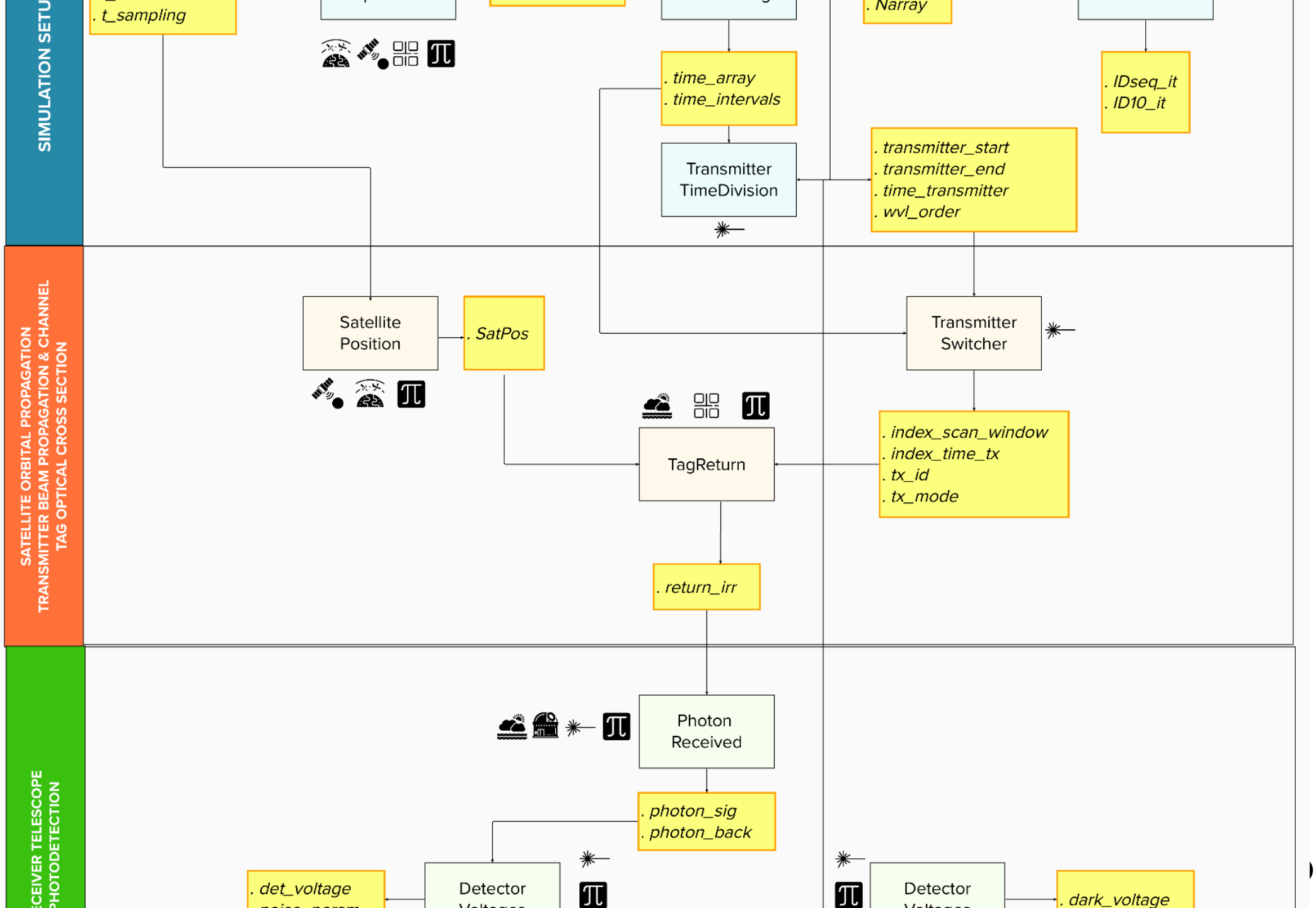
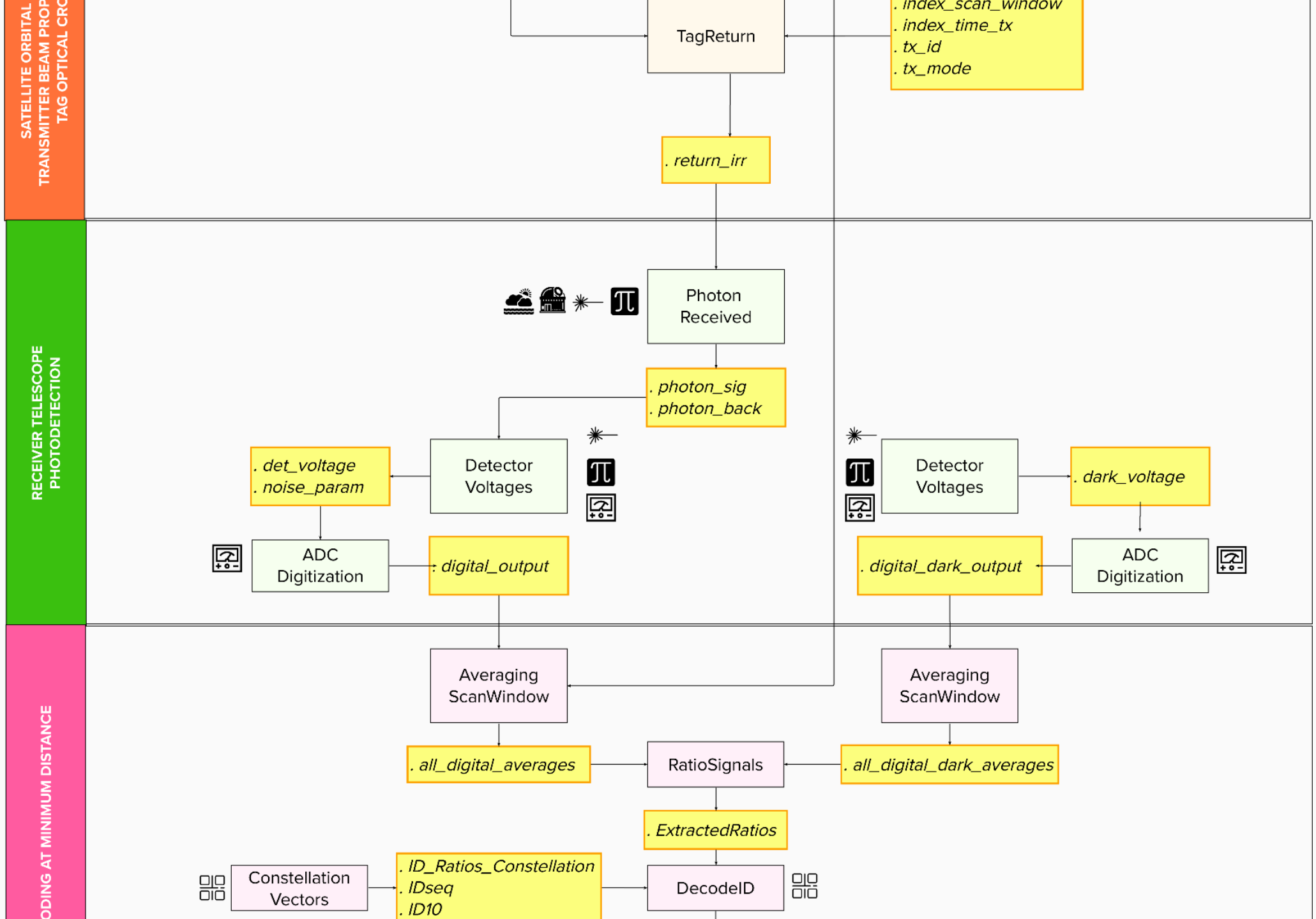
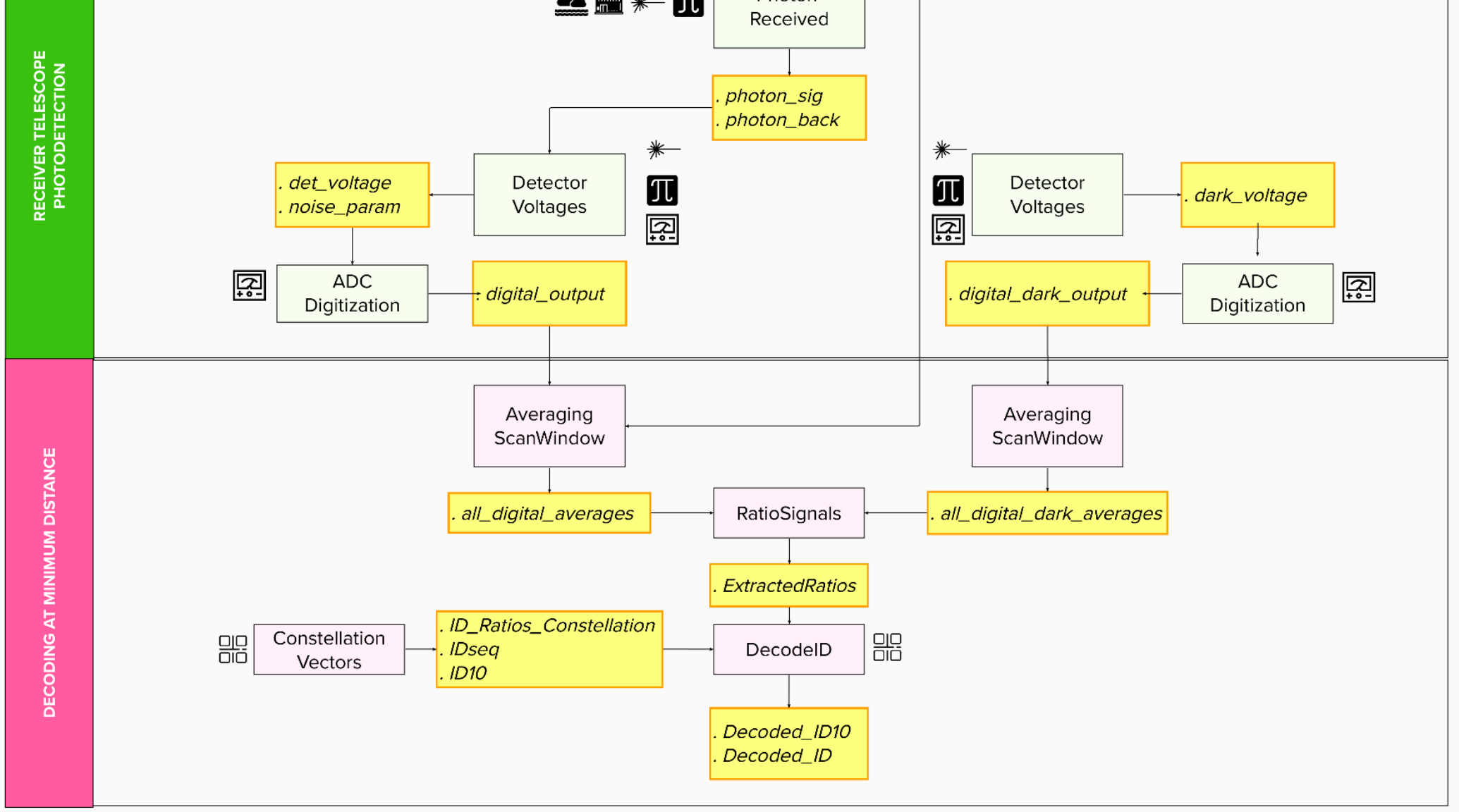

INPUT
Channel Template
Satellite Template
OGS Template
Transmitter Template
Receiver Template
Detector Template
Tag Template
Constant Template
SIMULATION SETUP
. date_day
. transmitter_start
. t_duration
. t_sampling
Scheduling Operation
. time_sim
Simulation TimeSettings
. time_array
. time_intervals
Transmitter TimeDivision
. Nwvl
. Nint
. Narray
ID Generation
. IDseq_it
. ID10_it
. transmitter_start
. transmitter_end
. time_transmitter
. wvl_order
Satellite Position
. SatPos
Transmitter Switcher
TagReturn
. index_scan_window
. index_time_tx
. tx_id
. tx_mode

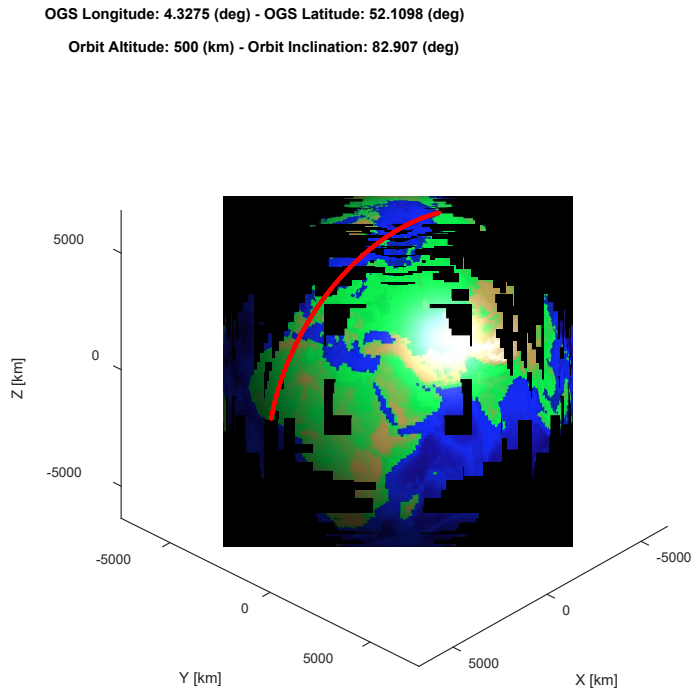

SIMULATION SETU
. t_sampling
. time_array
. time_intervals
Transmitter
TimeDivision
. transmitter_start
. transmitter_end
. time_transmitter
. wvl_order
. Narray
. IDseq_it
. ID10_it
SATELLITE ORBITAL PROPAGATION
TRANSMITTER BEAM PROPAGATION & CHANNEL
TAG OPTICAL CROSS SECTION
Satellite
Position
. SatPos
Transmitter
Switcher
TagReturn
. index_scan_window
. index_time_tx
. tx_id
. tx_mode
. return_irr
Photon
Received
. photon_sig
. photon_back
. det_voltage
Detector
Detector
. dark_voltage

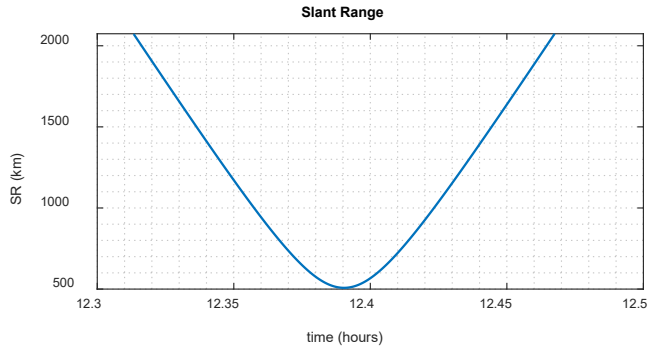

SATELLITE ORBITAL
TRANSMITTER BEAM PROP
TAG OPTICAL CRO
TagReturn
. index_scan_window
. index_time_tx
. tx_id
. tx_mode
. return_irr
RECEIVER TELESCOPE
PHOTODETECTION
Photon
Received
. photon_sig
. photon_back
. det_voltage
. noise_param
Detector
Voltages
ADC
Digitization
. digital_output
Detector
Voltages
. dark_voltage
. digital_dark_output
ADC
Digitization
Averaging
ScanWindow
Averaging
ScanWindow
. all_digital_averages
RatioSignals
. all_digital_dark_averages
. ExtractedRatios
Constellation
Vectors
. ID_Ratios_Constellation
. IDseq
. ID10
DecodeID

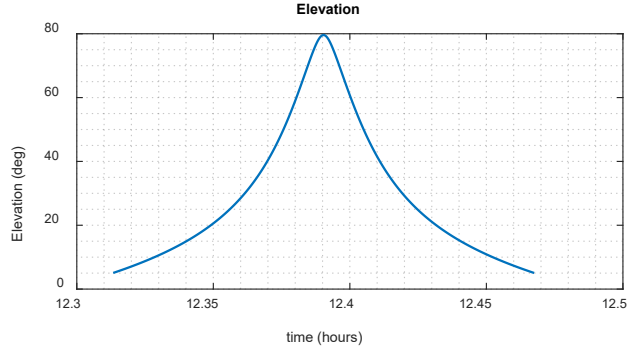
SL
SY

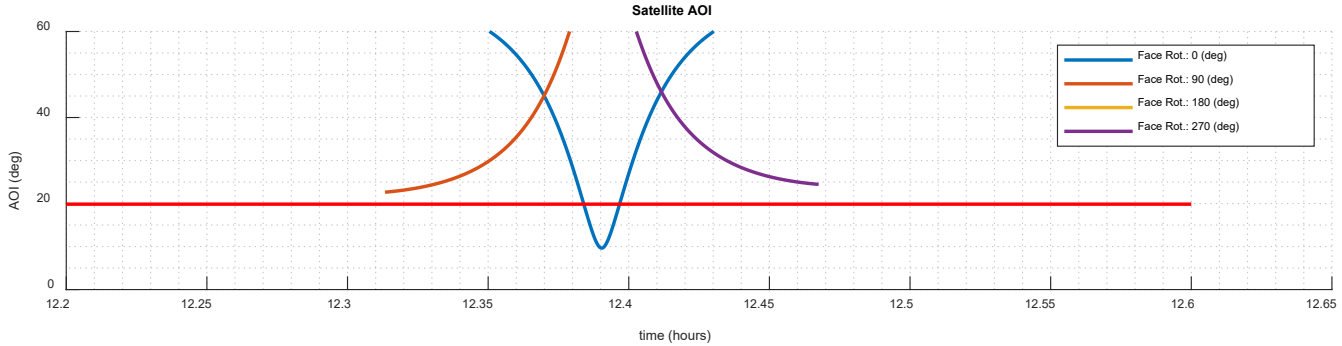

RECEIVER TELESCOPE PHOTODETECTION
Received
. photon_sig
. photon_back
. det_voltage
. noise_param
Detector Voltages
ADC Digitization
: digital_output
Detector Voltages
. dark_voltage
. digital_dark_output
ADC Digitization
DECODING AT MINIMUM DISTANCE
Averaging ScanWindow
Averaging ScanWindow
. all_digital_averages
RatioSignals
. all_digital_dark_averages
. ExtractedRatios
Constellation Vectors
. ID_Ratios_Constellation
. IDseq
. ID10
DecodeID
. Decoded_ID10
. Decoded_ID

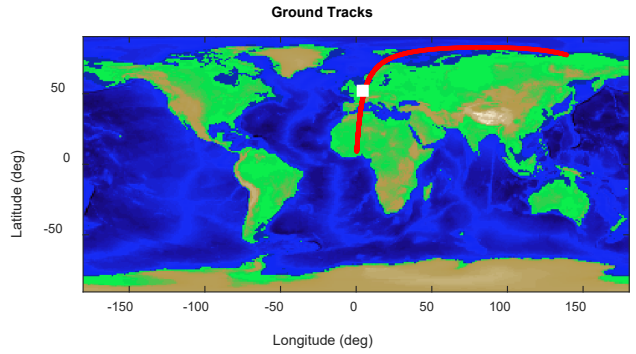
SLP SYSTEM PERFORMANCE MODEL

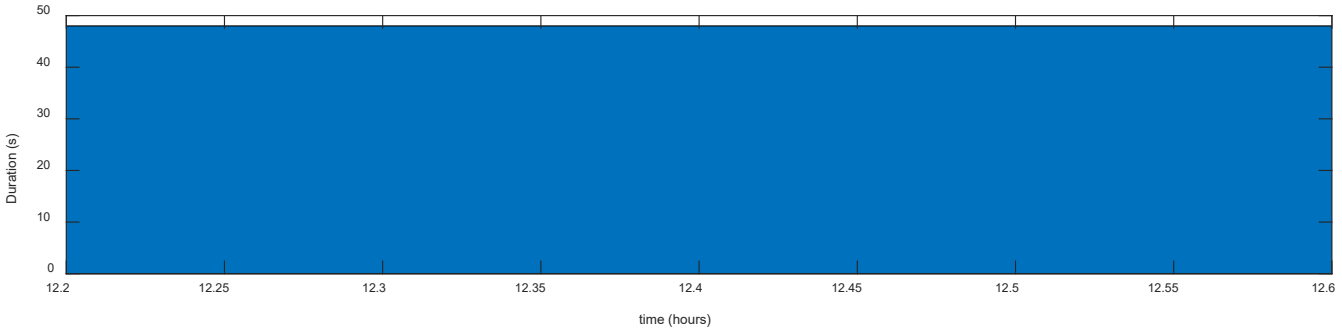






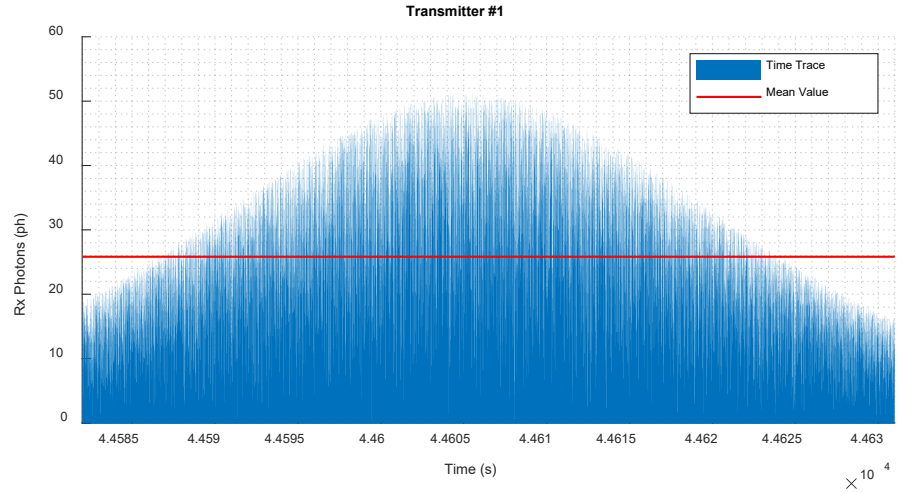


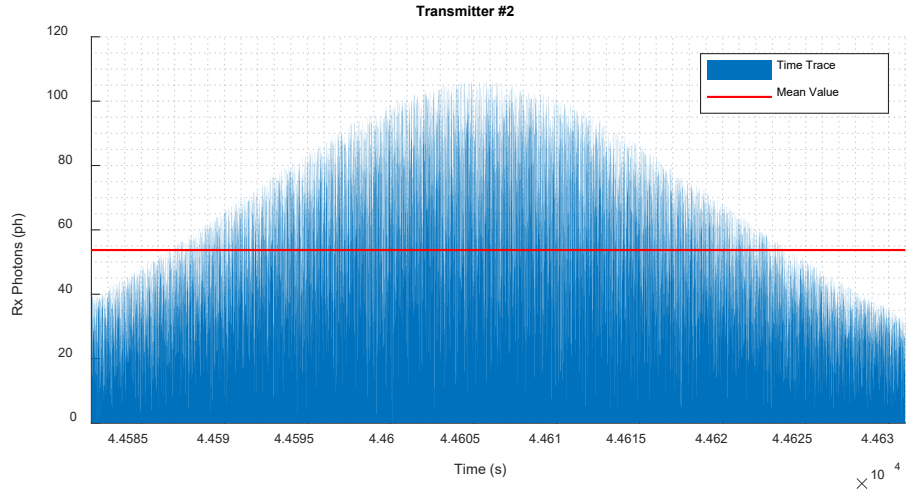


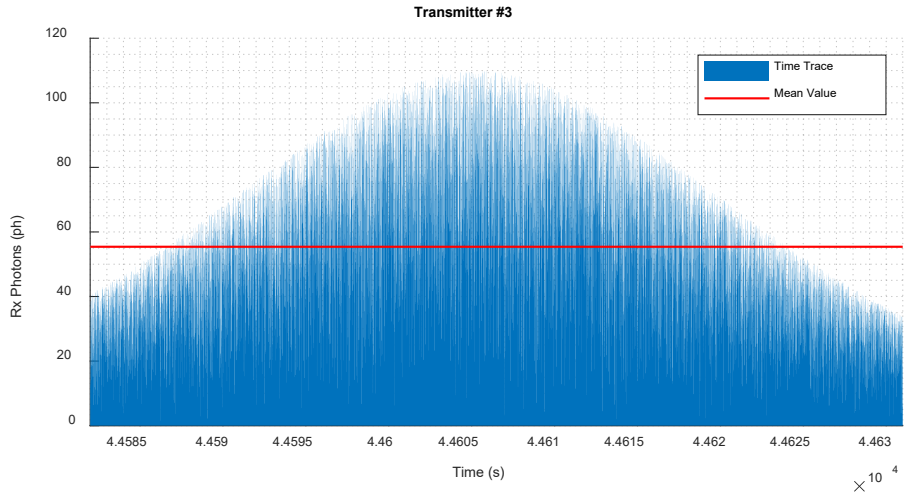


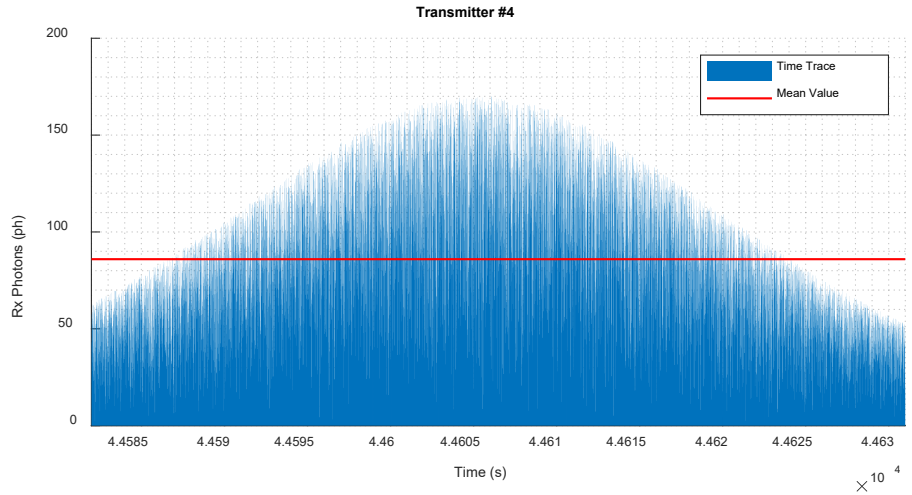
SLP SYSTEM PERFORMANCE MODEL

EXPECTED OUTPUT









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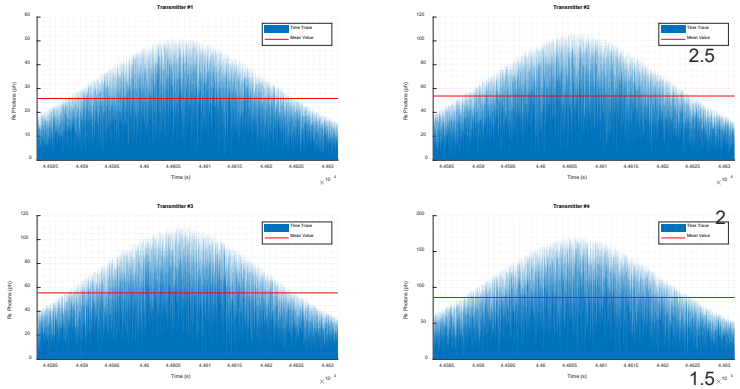
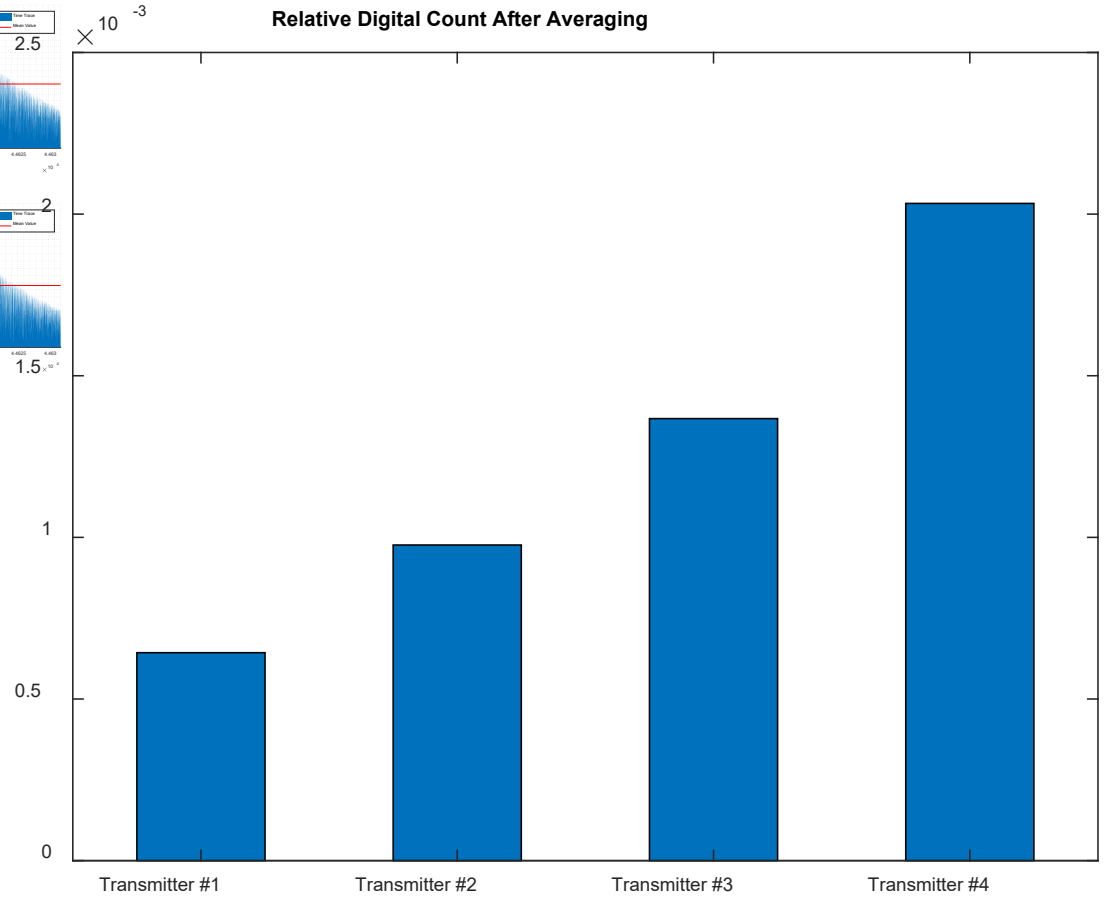
EXPECTED OUTPUT





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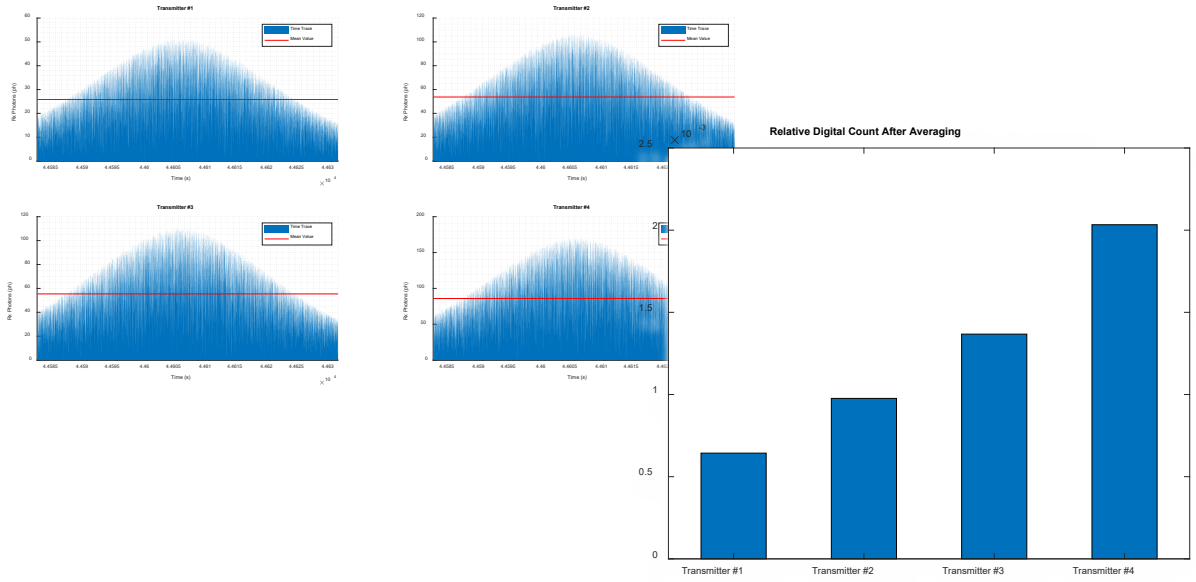
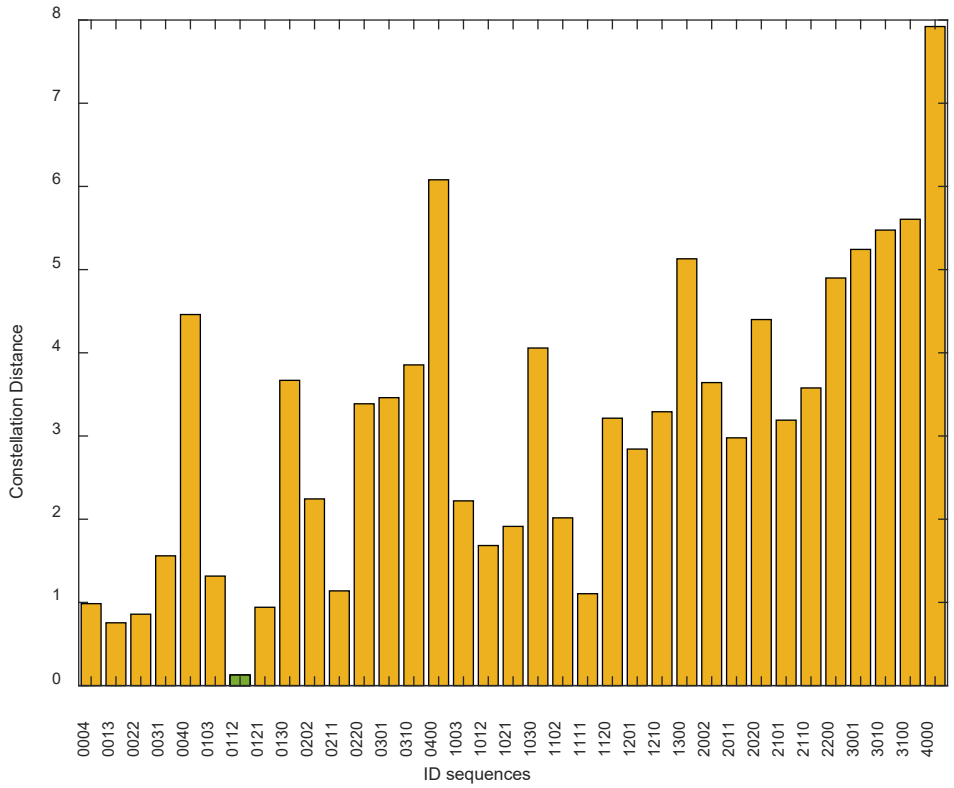
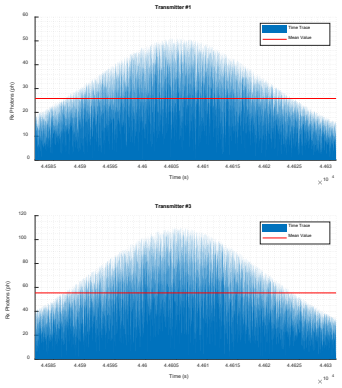
EXPECTED OUTPUT

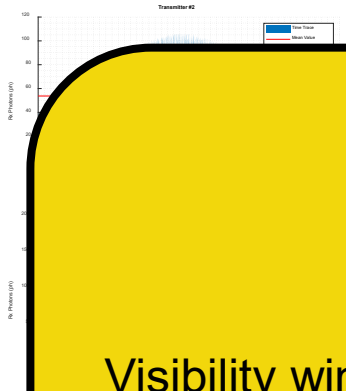




SLP SYSTEM PERFORMANCE MODEL

EXPECTED OUTPUT

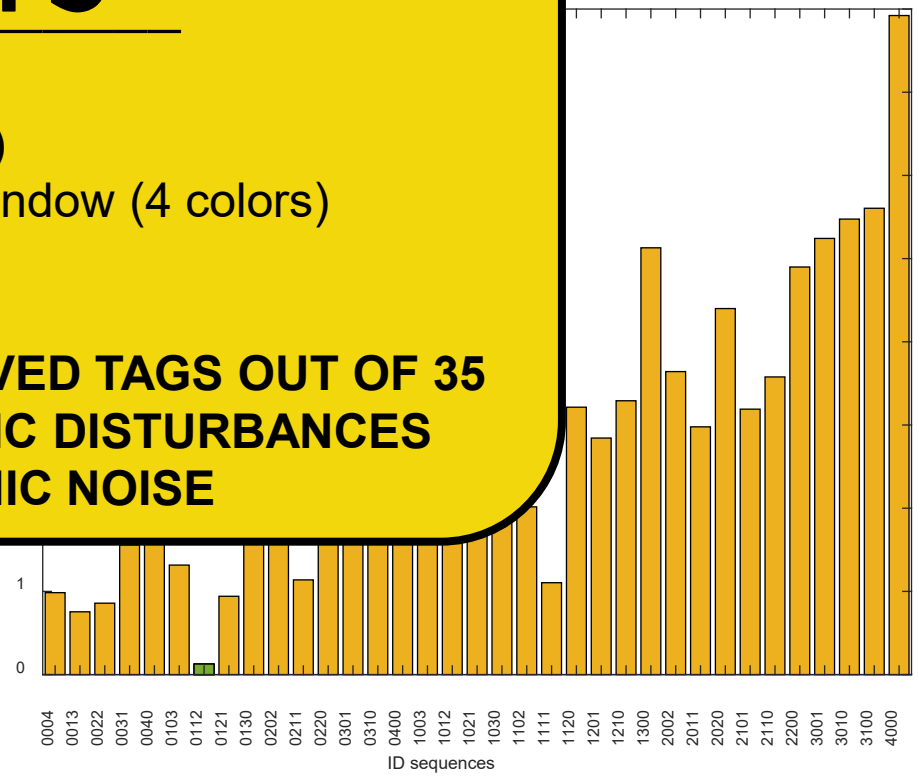




KEY FACTS

Visibility window: > 45 s (single pass)
Statistics >4500 interrogations per window (4 colors)
Pulse Energy: 70 µJ

SUCCESS RATE 97% = 34 RESOLVED TAGS OUT OF 35 IN PRESENCE OF ATMOSPHERIC DISTURBANCES AND OPTOELECTRONIC NOISE

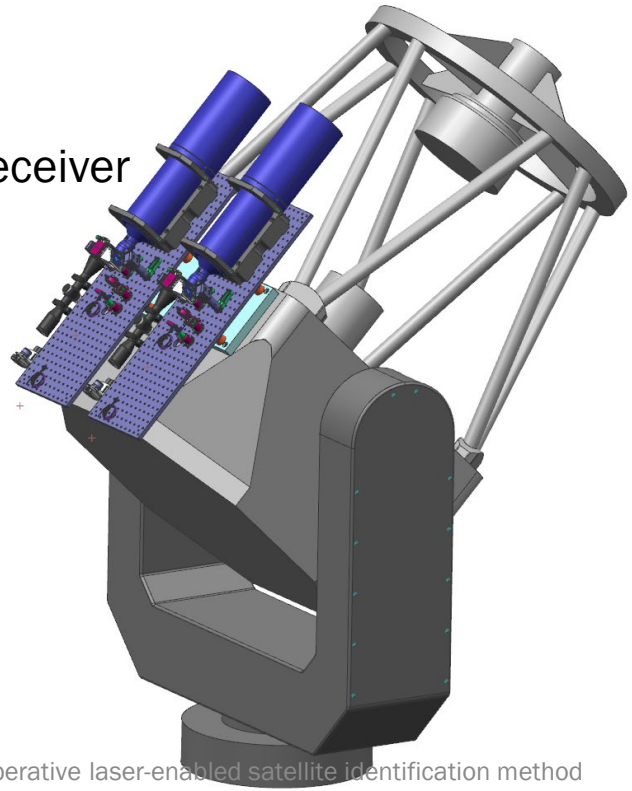


SLP CONCEPT

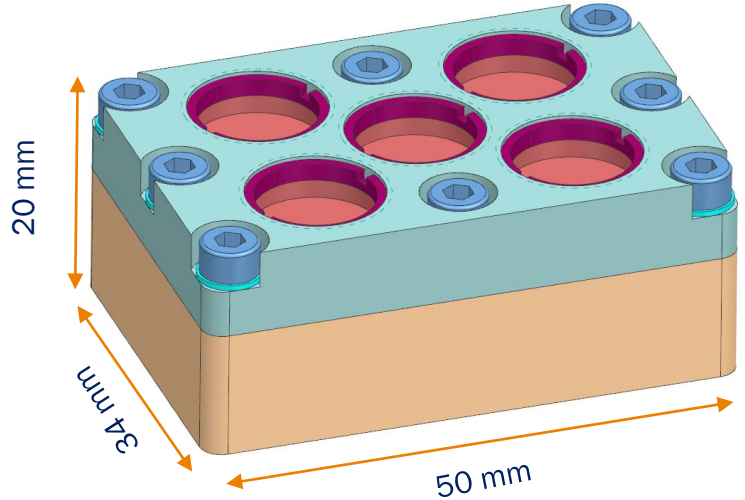
IDENTIFICATION CONCEPT

2011

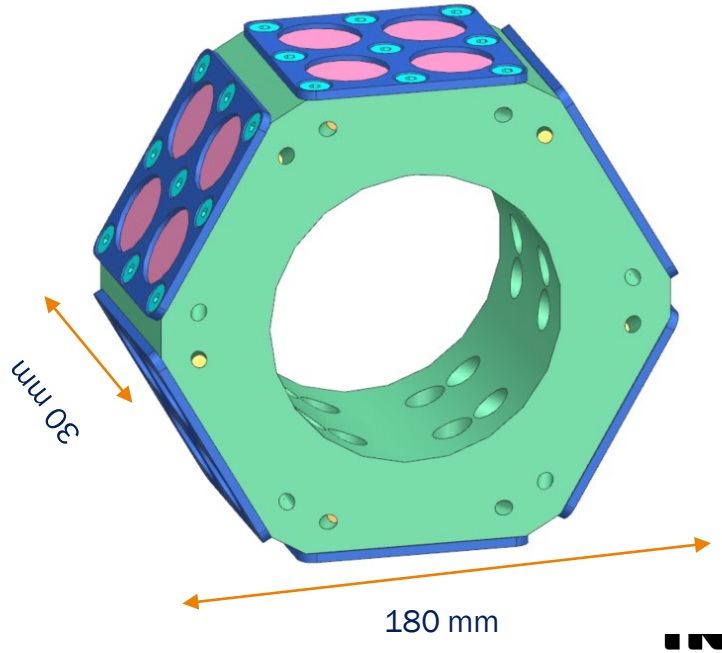
OGS
Transmitter & Receiver



Space TAG design



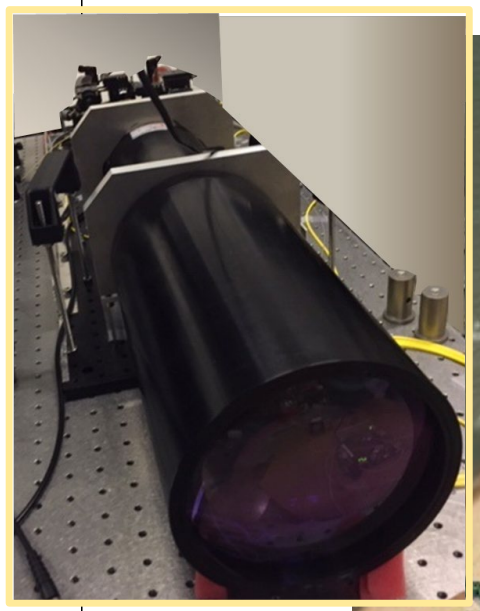
Multi-face TAG concept

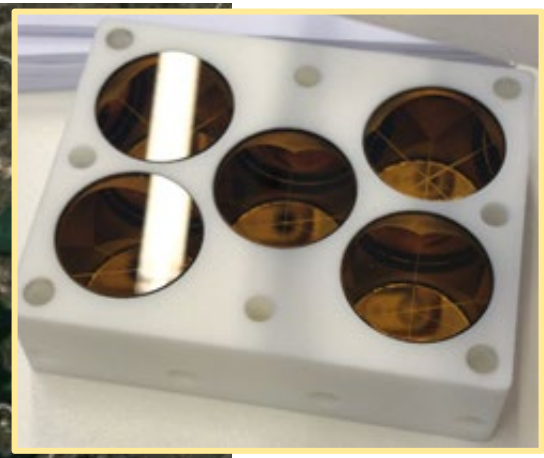


SLP PRELIMINARY TESTS

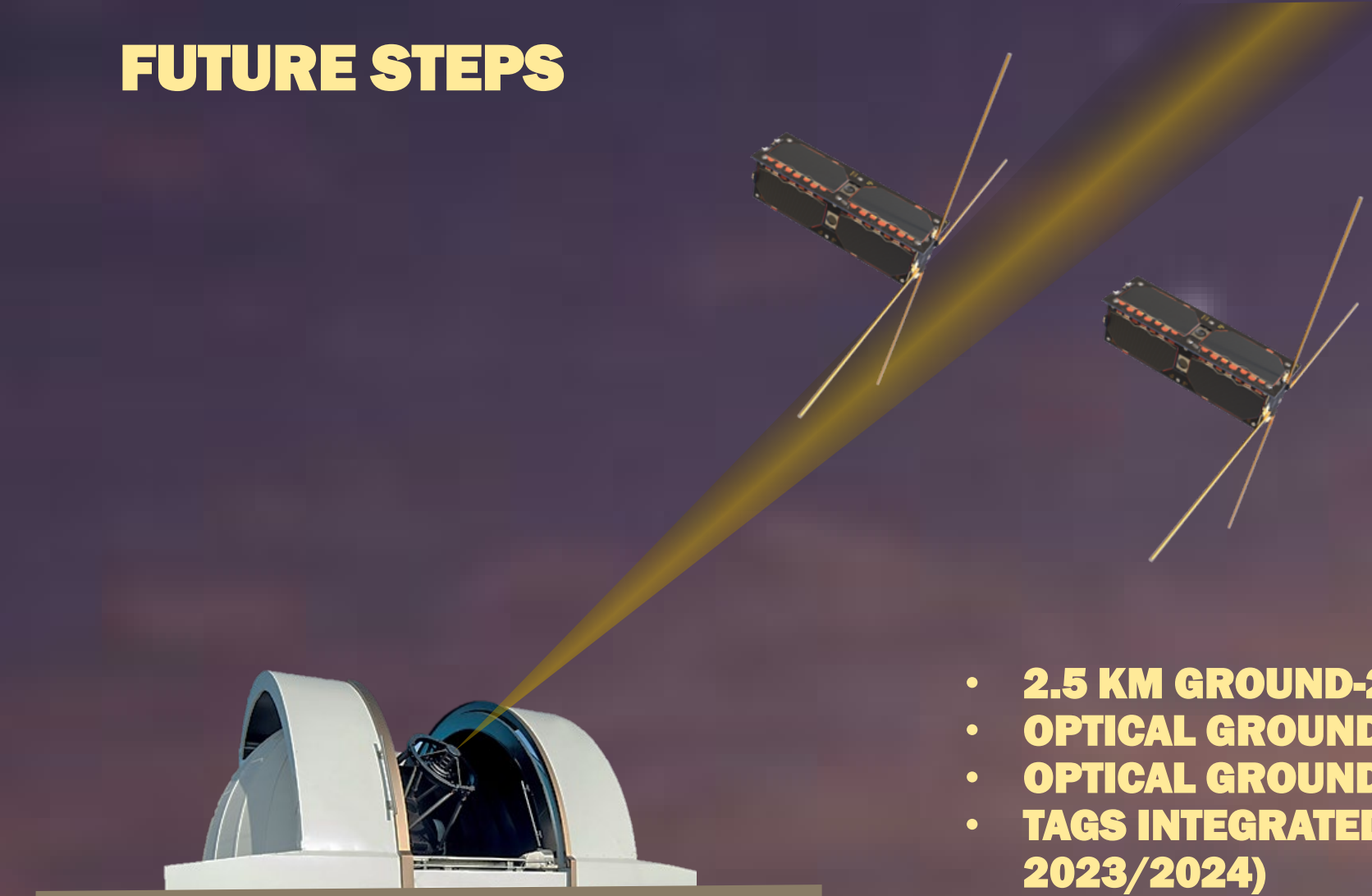
GROUND TO GROUND TESTS

- Functional tests planned for October-November 2022





FUTURE STEPS



- 2.5 KM GROUND-2-GROUND TESTS (2022)
- OPTICAL GROUND TERMINAL DESIGN (2022/2023)
- OPTICAL GROUND TERMINAL PRODUCTION (2023)
- TAGS INTEGRATED ON SATELLITES (LAUNCH 2023/2024)

- INTERESTED IN PARTNERSHIP ?

THANK YOU FOR
YOUR TIME