# B1 NAC/WAC

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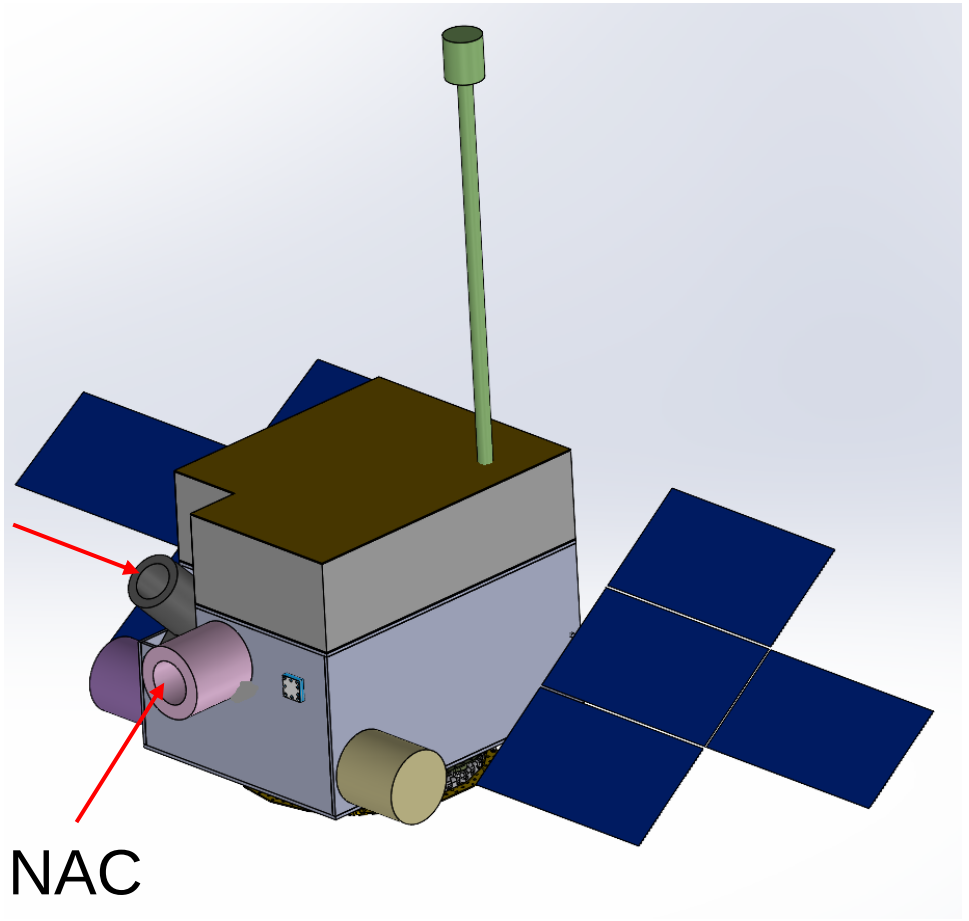
# B1 NAC/WAC

Science objectives

- Construct a global shape model of the nucleus in collaboration with the images taken by CoCa. [SciRD R0-N-10]
- Characterise the surface geomorphology on high latitude regions. [SciRD R0-N-30]
- Characterise the structure of the dust environment of the coma and determine any connection to the nucleus. [SciRD R0-C-30]





# Science requirements

- At closest approach, B1 NAC shall image the nucleus such that the entire nucleus is within the FoV of the instrument. [SciRD R2-P-006]

- B1 NAC shall carry out nucleus imaging of the high solar phase angle region near the CA at < 40 m resolution. [SciRD R2-P-020]

- B1-WAC shall carry out wide field imaging of coma [SciRD R2-P-152]

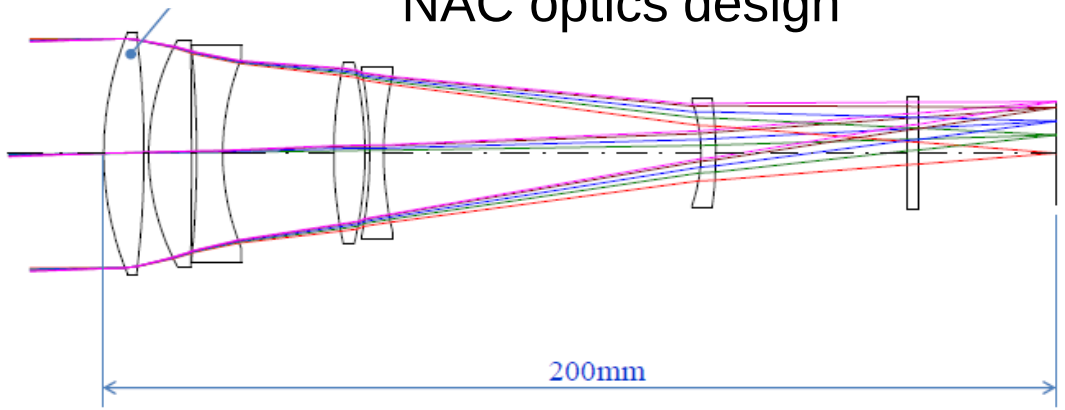
# NAC/WAC design

| | Narrow Angle Camera | Wide Angle Camera |
|---|---|---|
| Sensor | CCD | CMOS |
| Pixel number | 3296 x 2472 pix | 2048 x 2048 pix |
| Focal length | 300 mm | 8.6 mm |
| F-Number | 6.0 | 2.8 |
| FOV | 3.5 deg x 2.6 deg | 90 deg x 90 deg |
| iFOV | 0.018 mrad | 0.77 mrad |
| Filter | 0.4 – 0.75 μm | 0.4 – 0.75 μm |
| Size | 10 x 10 x 40 cm | 10 x 10 x 10 cm |
| Weight | ~ 4 kg | ~ 1 kg |

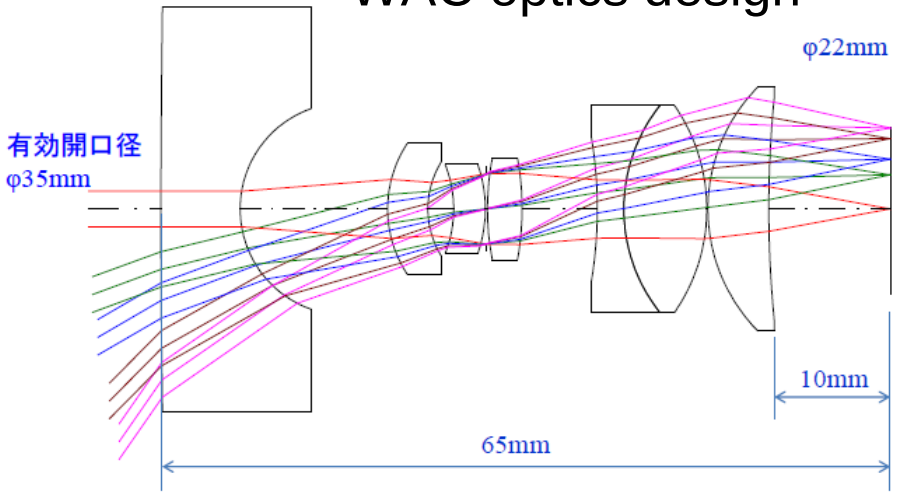
At the distance of 850 km

- NAC resolution = 15.6 m/pix
- WAC resolution = 540 m/pix

NAC optics design




WAC optics design



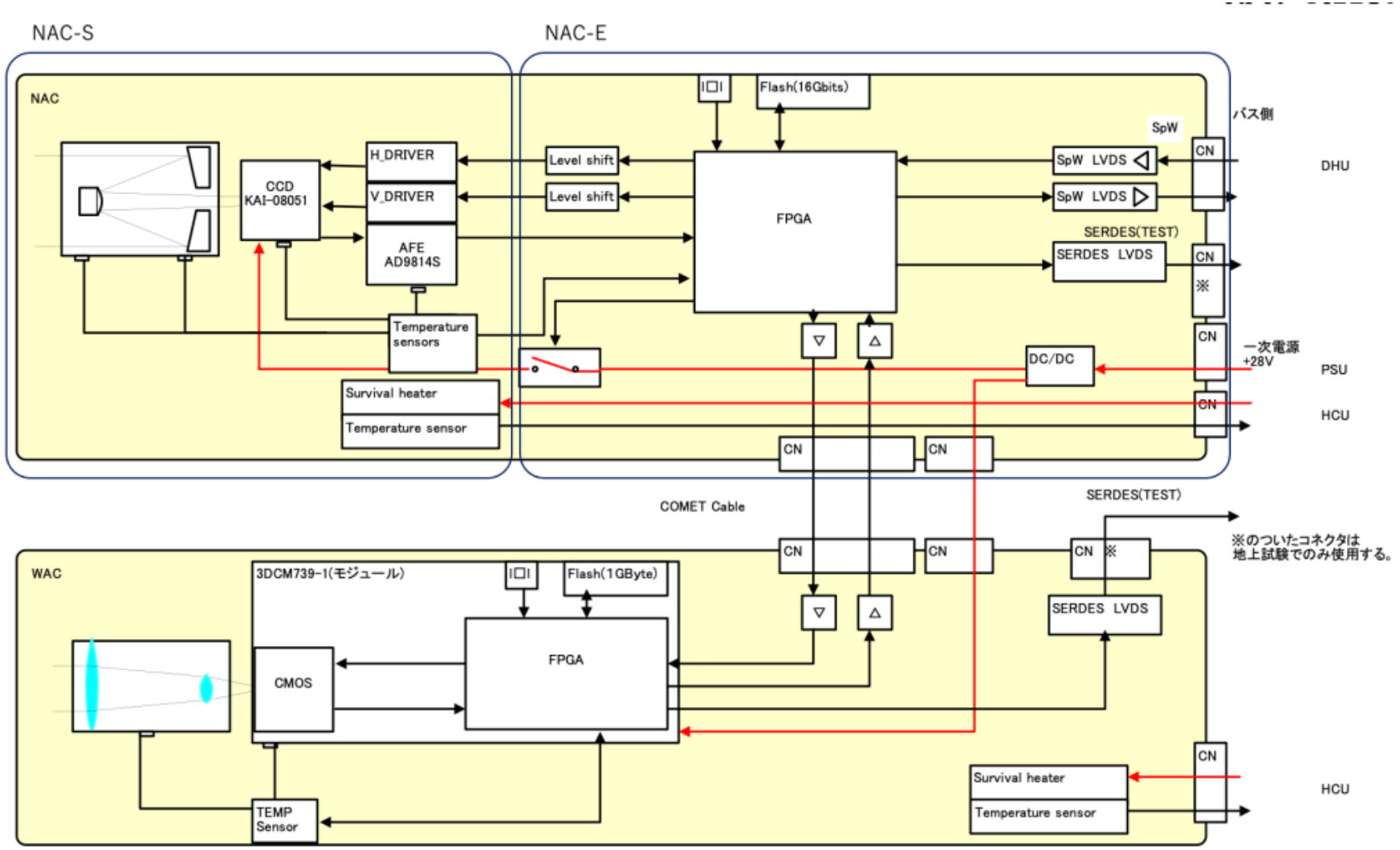
# Block diagram

Components

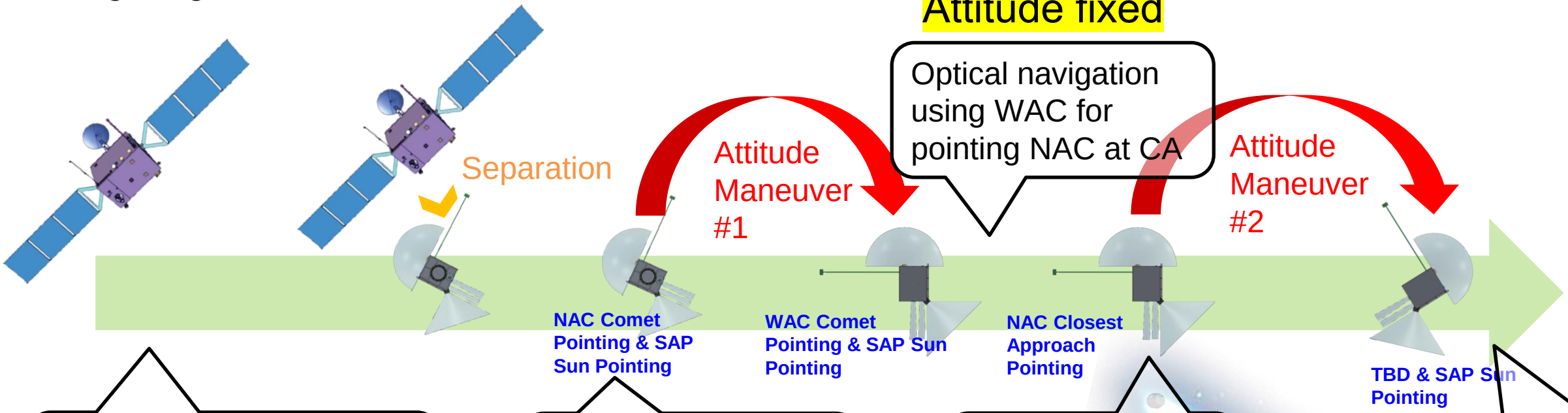
(1) NAC-E
- I/F with bus system
- Control of NAC/WAC sensors
- Image processing

(2) NAC-S
- CCD imaging sensor
- Optics

(3) WAC
- CMOS imaging sensor
- Optics



# Flyby observations




Upload preset commands for all observations during the flyby

NAC/WAC Continuous imaging (1frame/30min, TBD)

Science output
- Light curve
- Large structure of coma

NAC observations at CA

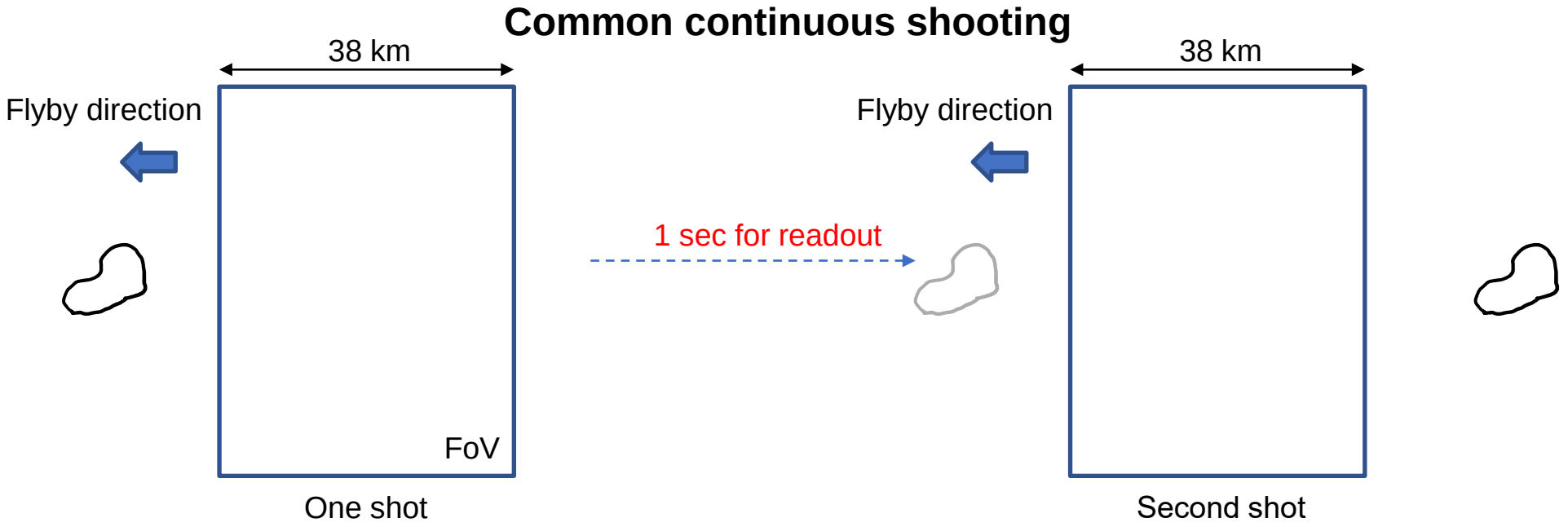
Science output
- Nucleus shape
- Surface geomorphology

NAC/WAC Continuous imaging (1frame/30min, TBD)

Science output
- Light curve
- Large structure of coma

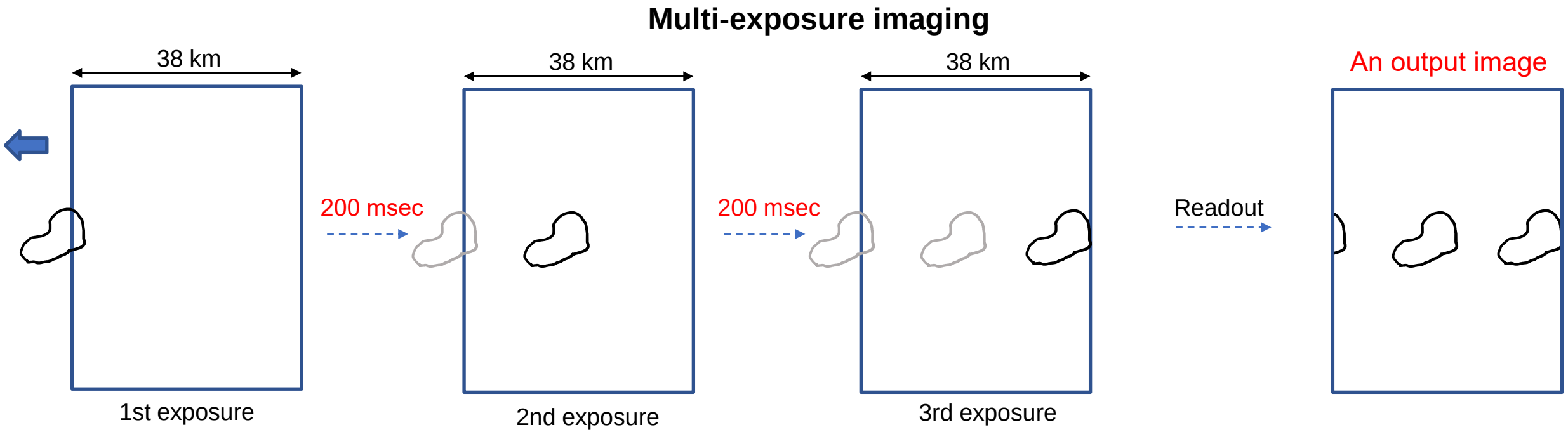
# Issue on NAC observations at CA

- Because of the high-speed flyby without tracking mirror system, continuous shooting (1 frame/sec, dominated by charge readout time) at closest approach is risky.
- The field of view of NAC is 38 km at 850 km distance, and the duration, in which the 10 km nucleus is in the FoV, is 0.4 sec assuming the relative velocity of 70 km.



# NAC multi-exposure function

- Exposures are repeated by suitable interval without reading the electrons from CCD.
- We can image the nucleus even if the closest approach timing is uncertain.
- Confirmed by BBM test in 2021.



# NAC TDI imaging function

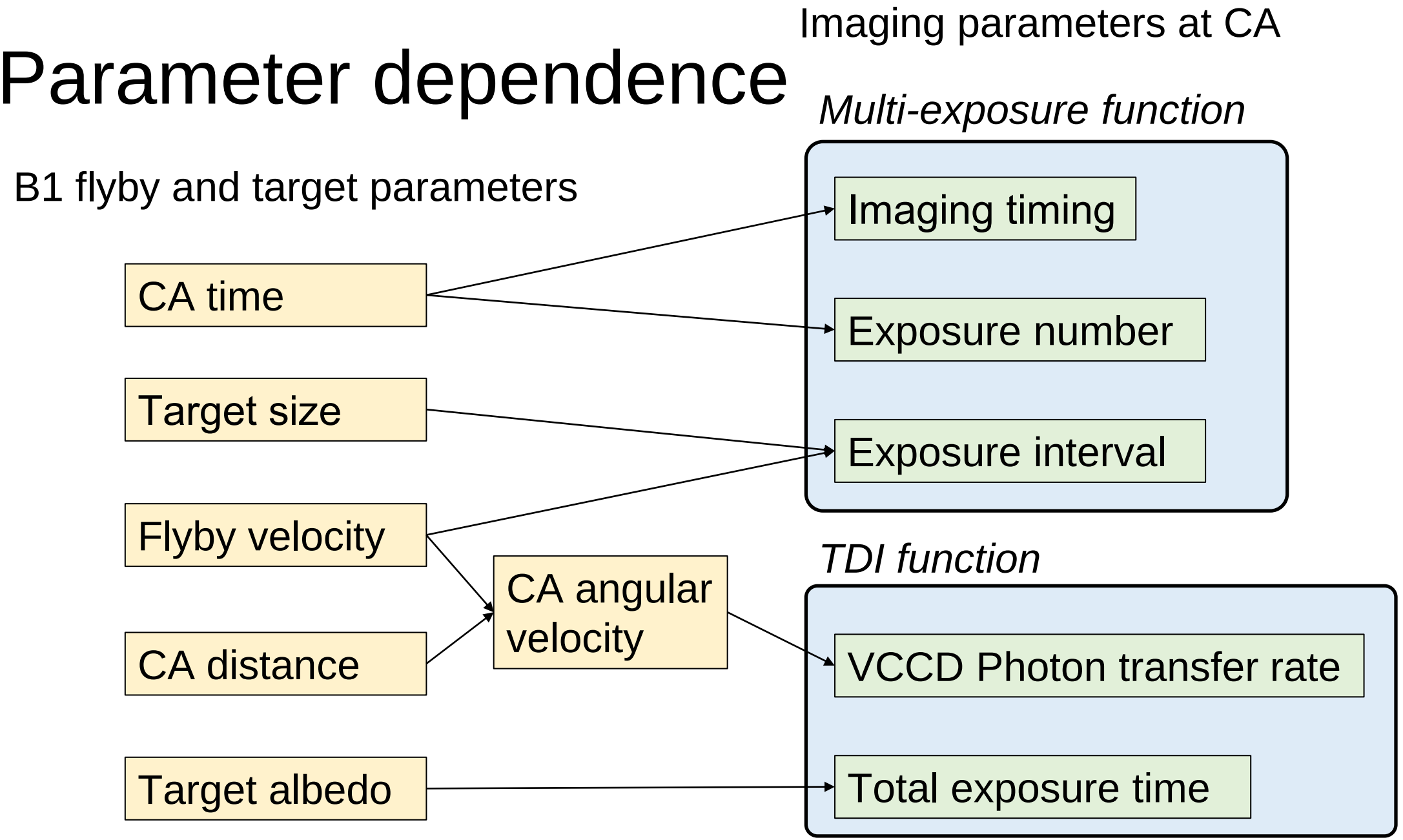
- **Time Delay Integration (TDI)**
  - A technique to observe the high-speed target with high S/N ratio.
  - Short exposure, reading (electron transfer from photodiodes to CCDs), and electron transfer to next CCDs are repeated with synchronizing with the moving target.
  - TDI imaging test using BBM is now prepared in Rikkyo University.

without TDI

with TDI

https://www.satnavi.jaxa.jp/project/slats/slats-interview-03.html

# Parameter dependence



# Parameter dependence

B1 flyby and target parameters

**High uncertainty**

CA time

1σ = 100 s (worst case)

Target size

Flyby velocity

**High uncertainty**

CA angular velocity

**High uncertainty**

CA distance

1σ = 250 km (nominal dist. = 850 km)

Target albedo

Imaging parameters at CA

Onboard update of the CA time and CA distance (or angular velocity) is essential for successful NAC imaging of the target.

(1) CA time error shall be less than +/-5 sec.

(2) CA angular velocity error shall be less than some value so that the TDI imaging smear is smaller than 2 pix.

Exposure interval

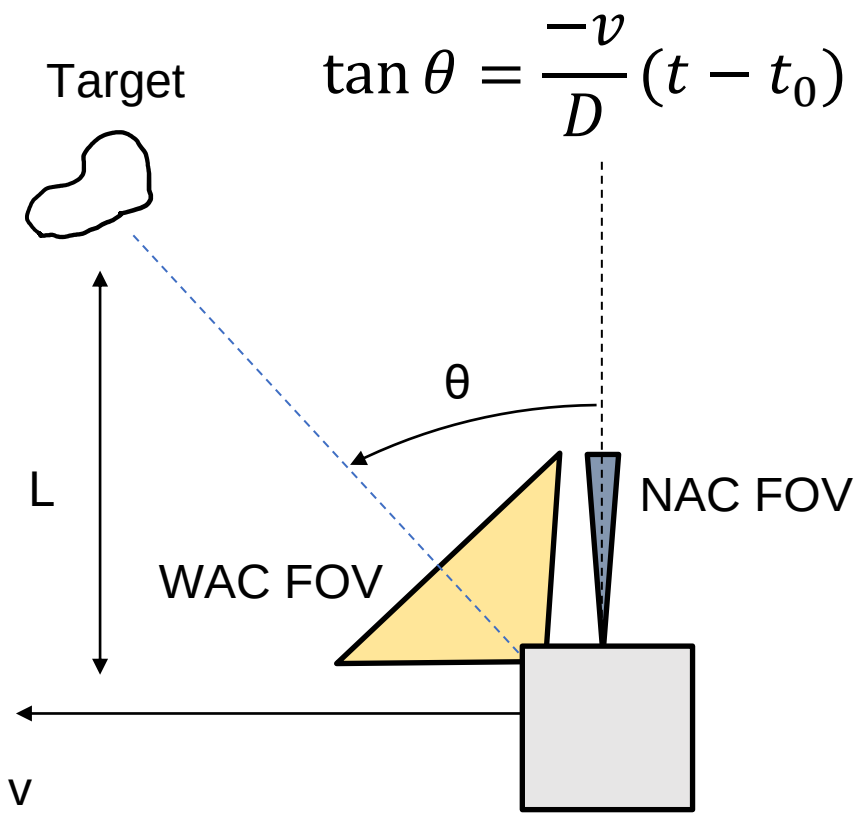
*TDI function*

VCCD Photon transfer rate

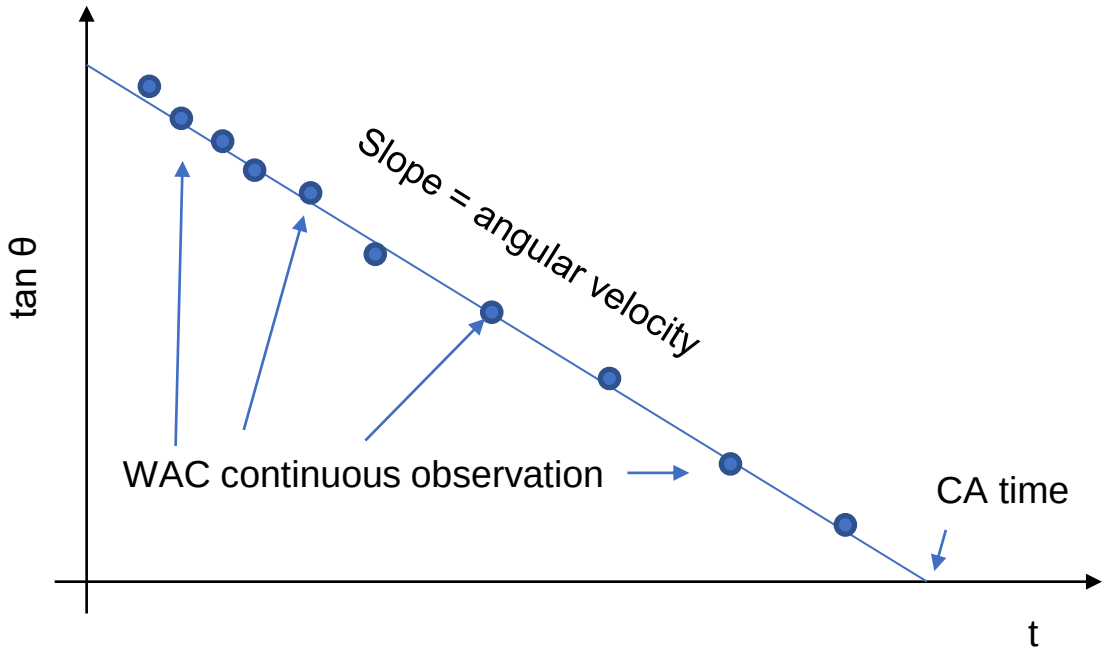
Total exposure time

# WAC observations just before CA

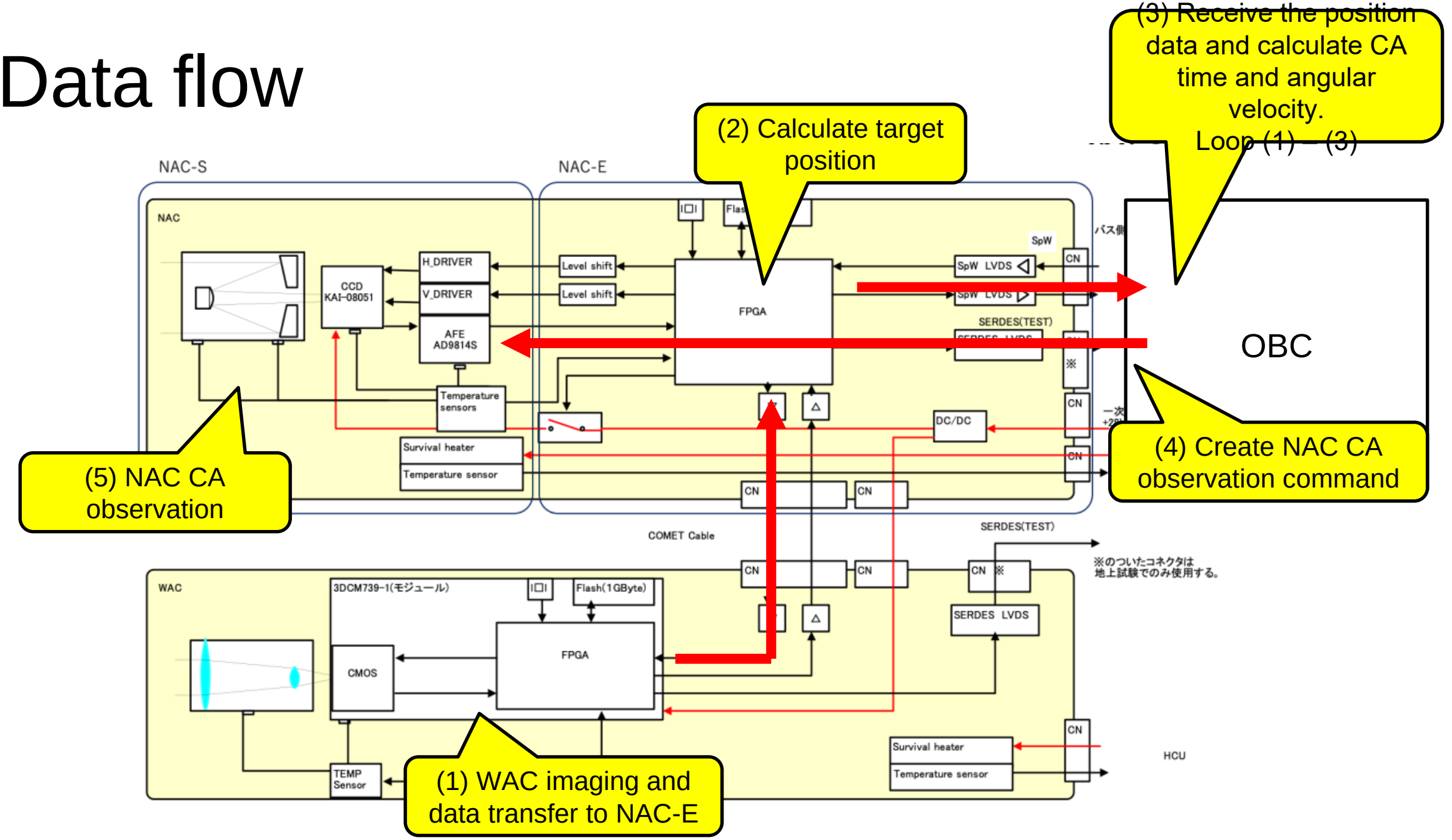
Purpose : Estimate the CA time and angular velocity




CA time : t = t0, time when θ = 0.
Angular velocity : v/D = slope of tanθ – t diagram



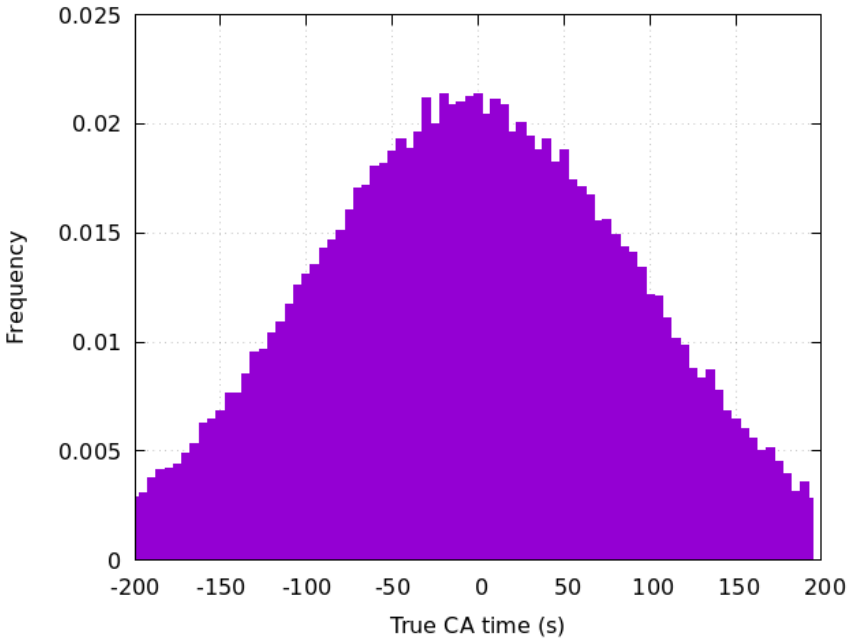
# Data flow

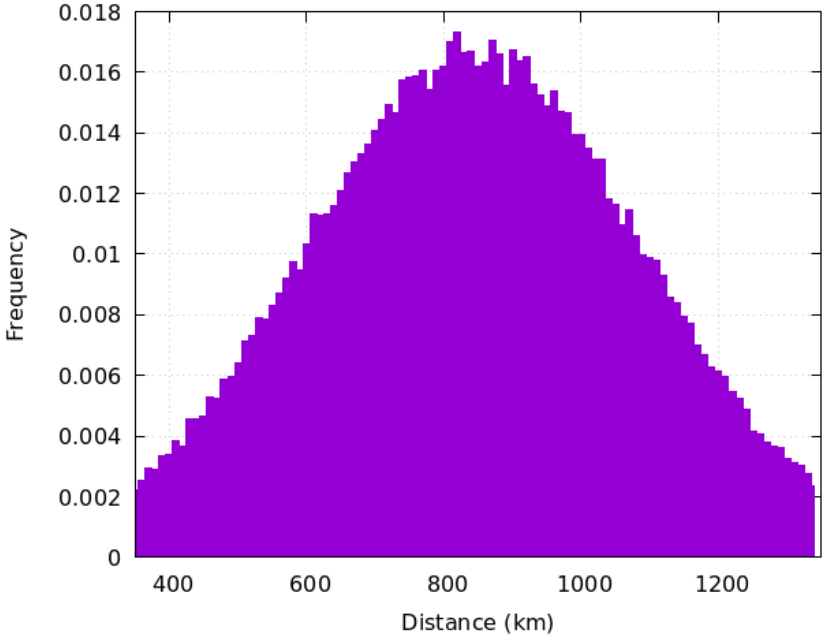

(3) Receive the position data and calculate CA time and angular velocity.
Loop (1) – (3)
(2) Calculate target position
NAC-S
NAC-E
NAC
CCD KAI-08051
H_DRIVER
V_DRIVER
AFE AD9814S
Level shift
Level shift
FPGA
SpW
SpW LVDS
SpW LVDS
SERDES(TEST)
CN
※
OBC
Temperature sensors
Survival heater
Temperature sensor
DC/DC
CN
CN
CN
CN
(5) NAC CA observation
(4) Create NAC CA observation command
COMET Cable
SERDES(TEST)
※のついたコネクタは
地上試験でのみ使用する。
WAC
3DCM739-1(モジュール)
Flash(1GByte)
CMOS
FPGA
SERDES LVDS
CN
CN
CN ※
TEMP Sensor
Survival heater
Temperature sensor
CN
HCU
(1) WAC imaging and data transfer to NAC-E

# Monte-Carlo simulation

- WAC imaging every 10 sec from 250 sec before (a priori) CA time.
- Target position has uncertainty in 5 pixels on WAC images.
- For each imaging, CA time and angular velocity are calculated.
- CA time has an error following the gaussian distribution with 1σ = 1000/v sec (upper left data).
- CA distance is 850 km in nominal and has an error following the gaussian distribution with 1σ = 250 km (bottom left data).
- The flyby velocity is fixed at 70 km/sec.
- The continuous imaging continues until the time is 15 sec before the estimated CA time.
- 100k trials.

Input data



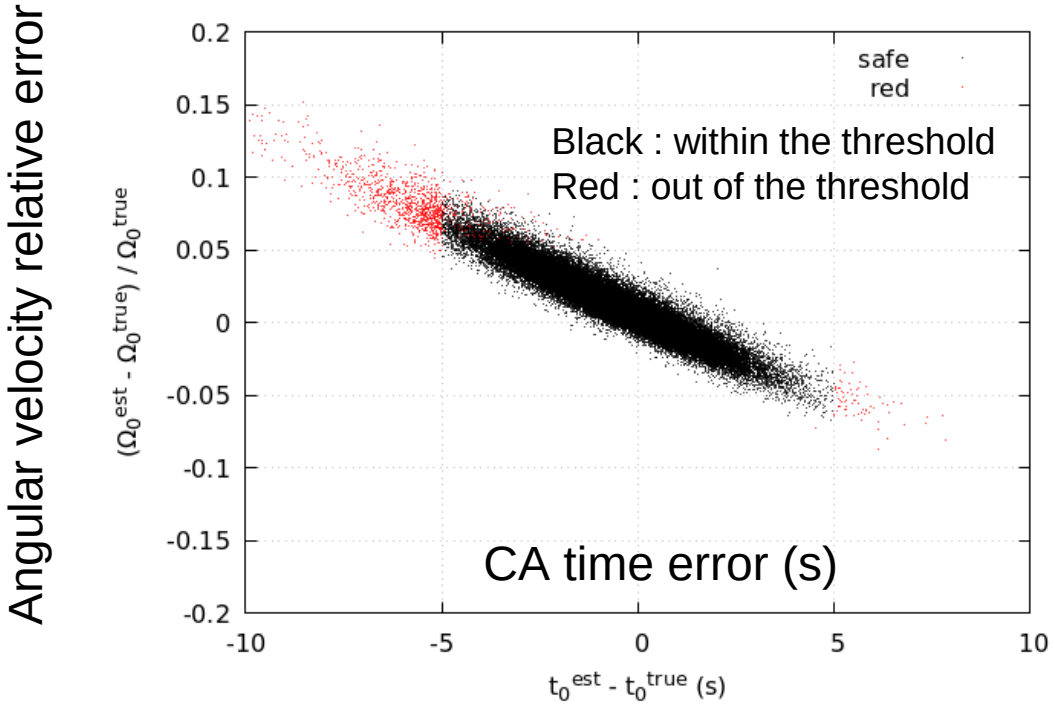



# Monte-Carlo simulation

Thresholds

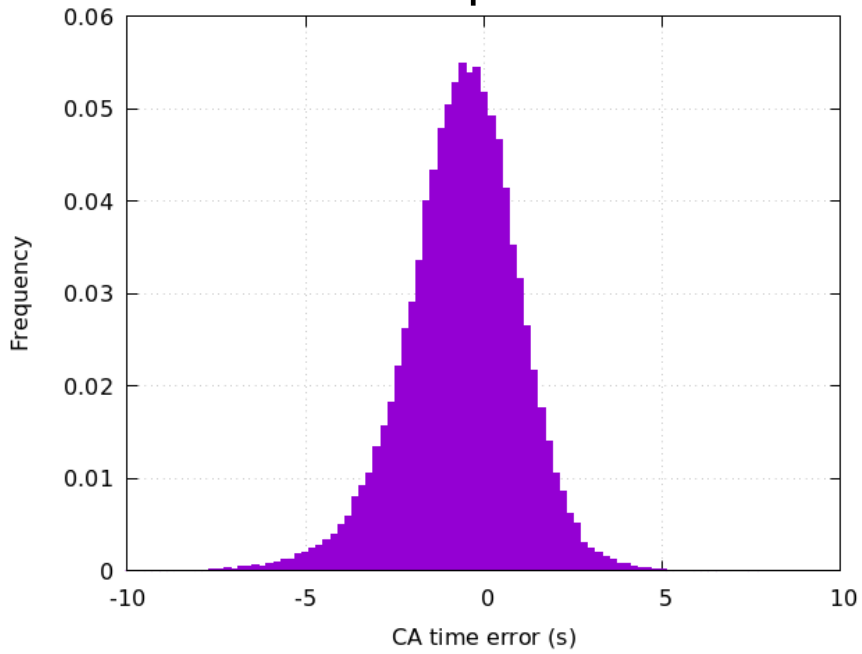
(1) CA time error shall be less than +/-5 sec.

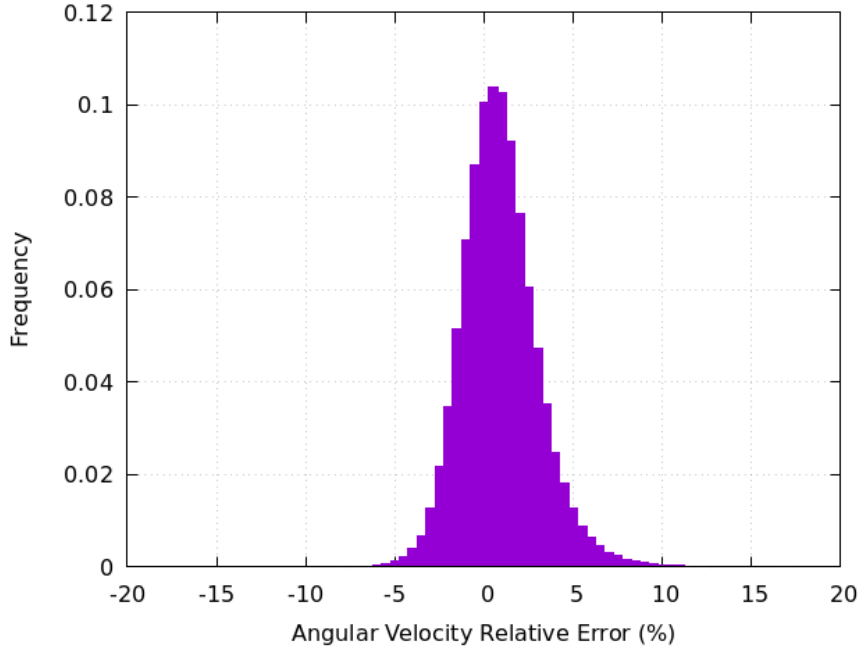
(2) CA angular velocity error shall be less than some value so that the TDI imaging smear is smaller than 2 pix.




98% of the trials satisfy the thresholds.

Outputs



# Summary

- NAC observes the comet nucleus at the closest approach using multi-exposure and TDI functions.
- The feasibility of the concept for the onboard estimate of the CA time and angular velocity with WAC observations was demonstrated.
- Next step
  - The detailed feasibility study including the navigation error to the CA attitude, alignment accuracy between NAC and WAC, and dust impacts.
  - Electrical designing of the components

Expected NAC image
at CA distance of 850 km