Low Cost Remote Sensing for Precision Farming using UAVs

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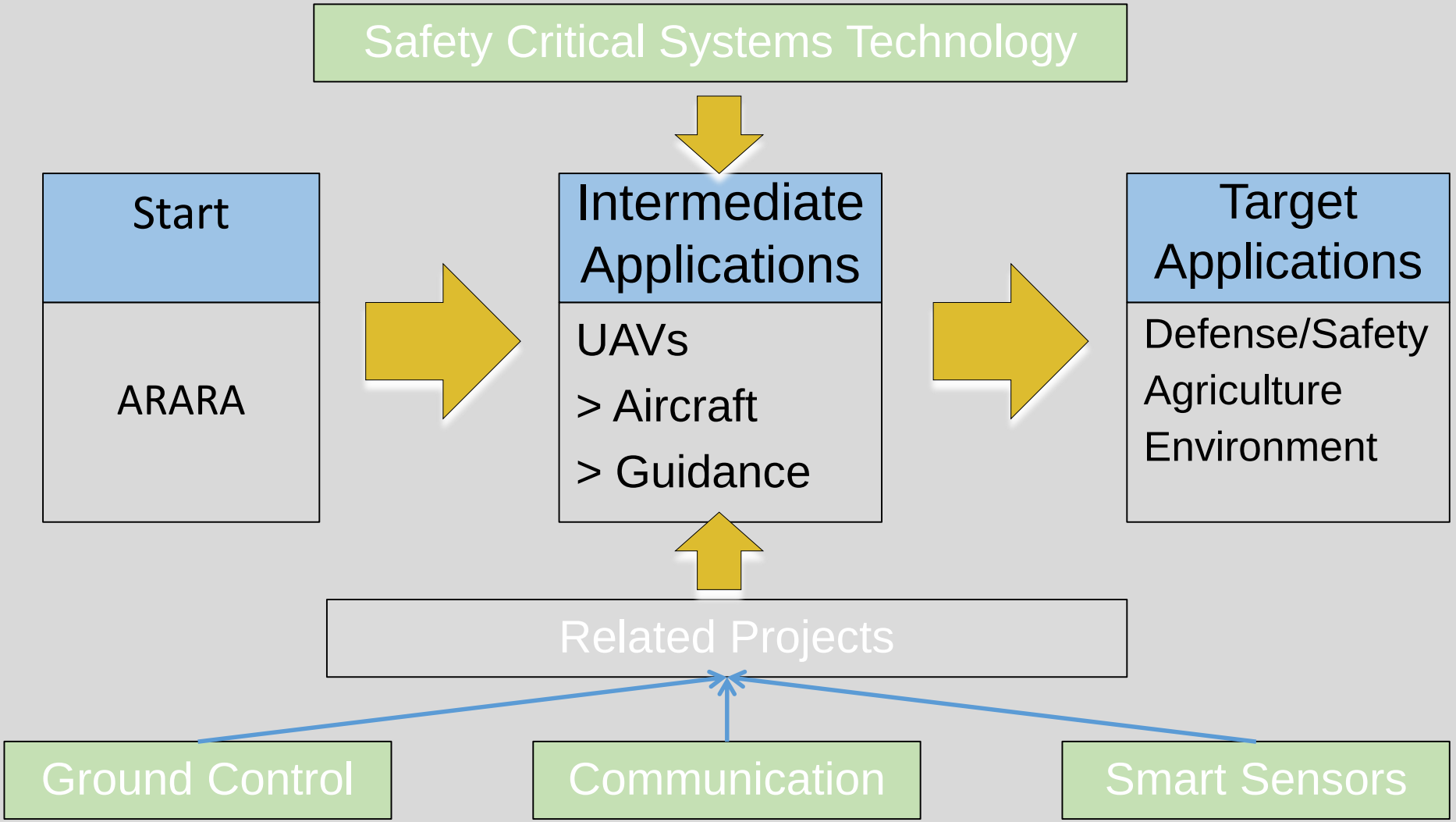
João Pessoa – Abril 2015

Summary

- Research on UAS in the ICMC-USP
  - The ARARA Project
  - Arara
  - INCT-SEC
    - Tiriba
    - AP1
    - AP2
  - Ararinha
  - SARVant
  - Tiriba MIL
  - Tuim & Agilis
- Precision Farming
- Structuring an UAS – A Flight Services Provider
  - The Payload – MOSA
  - The Safety Supervisor – IFA
- Success Metrics and Failure Rates
  - Aplying IFA2S
- Low Cost Systems
- The Good News
- Final Remarks

Research on UAS in the ICMC-USP



The ARARA Project

- ARARA stands for Autonomous and Radio Assisted Reconnaissance Aircraft

- The ARARA project started in 1997 aiming at the use of unmanned aircraft for crop monitoring and the surveillance of areas under environmental stress

The ARARA Project

- Phase 1 – Radio controlled aircraft (model airplanes). Geo-referenced images using on-board GPS. Flights under eyesight range (finished in 2000)
- Phase 2 – Custom designed aircraft. Complete on-board instrumentation. Ground control station. Instrument flights, beyond eyesight range. (finished in 2003)
- Phase 3 – Auto pilot, moving ground control station. (finished in 2006)
- Phase 4 – New hardware and software architectures, on-board image processing, new data link technology, larger autonomy

ARARA / ARARA NG

- Operating data
  - Engine ~~40~~ 55cc, ~~2~~ 4T, 5HP, AVGAS
  - Max weight : ~~20Kg~~ 16Kg
  - Payload: ~~3kg~~ 4Kg
  - Flight endurance: ~~4h~~ 8h
  - Cruise speed : ~~100~~ 200km/h
  - Stall speed : ~~40~~ 60 km/h
  - Autonomous or remote controlled aircraft
  - Emergency parachute
  - Electric generator/engine starter
  - Moving ground control station
  - Autonomous takeoff (on a car) and landing (on skis)

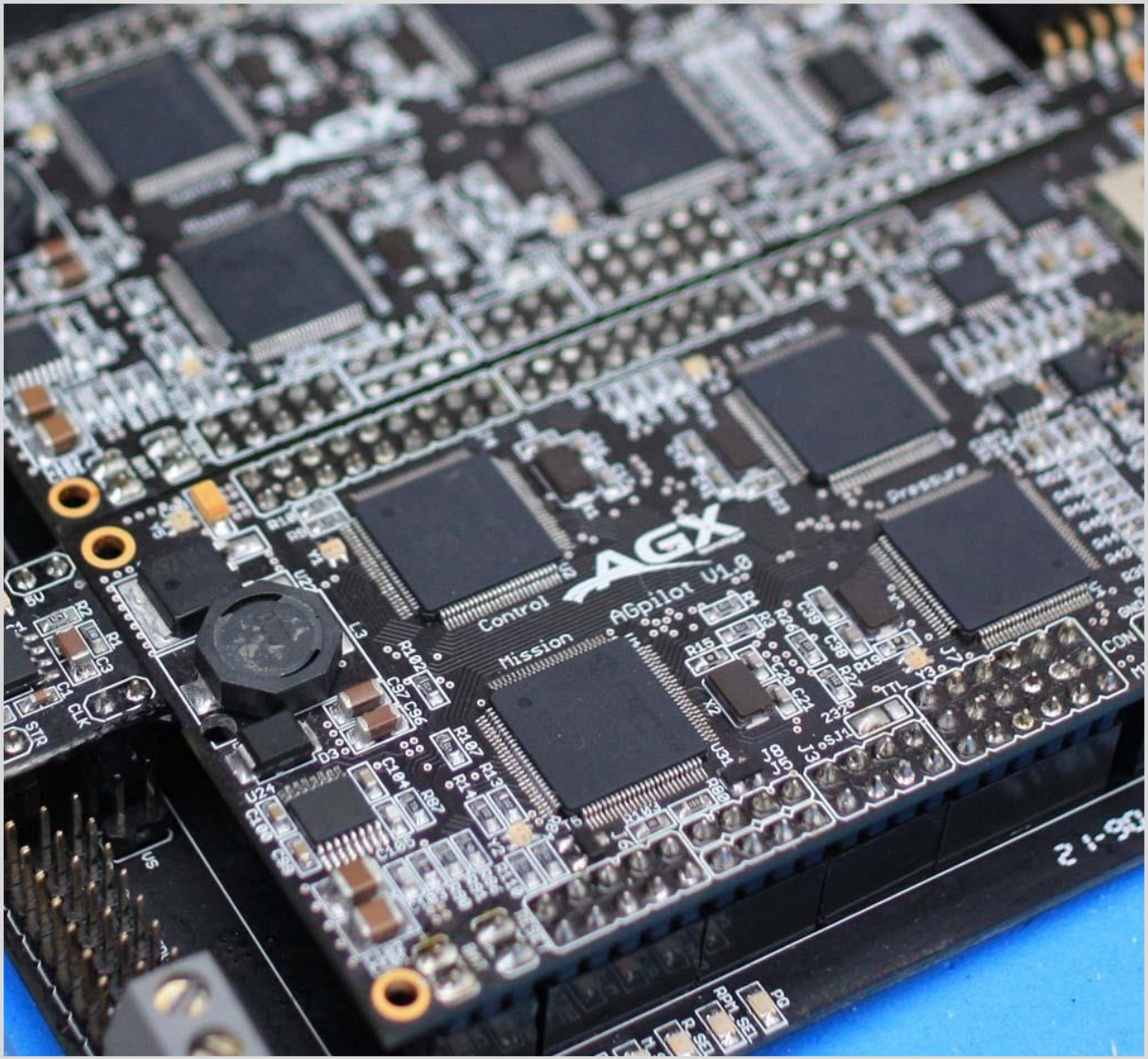
INCT-Sec Tiriba

- Electric propulsion
- Max takeoff weight: 4kg
- Payload: 800 g
- Autonomy: 45 min
- Cruiser speed: 100km/h
- Stoll speed: 40km/h
- Autonomous or remote controlled flight
- Landing – automatic parachute landing, manual belly landing
- Takeoff – automatic hand launch

INCT-Sec Autopilot

INCT-Sec Autopilot
3way redundant - SarVANT

Tree way redundancy



Open Source

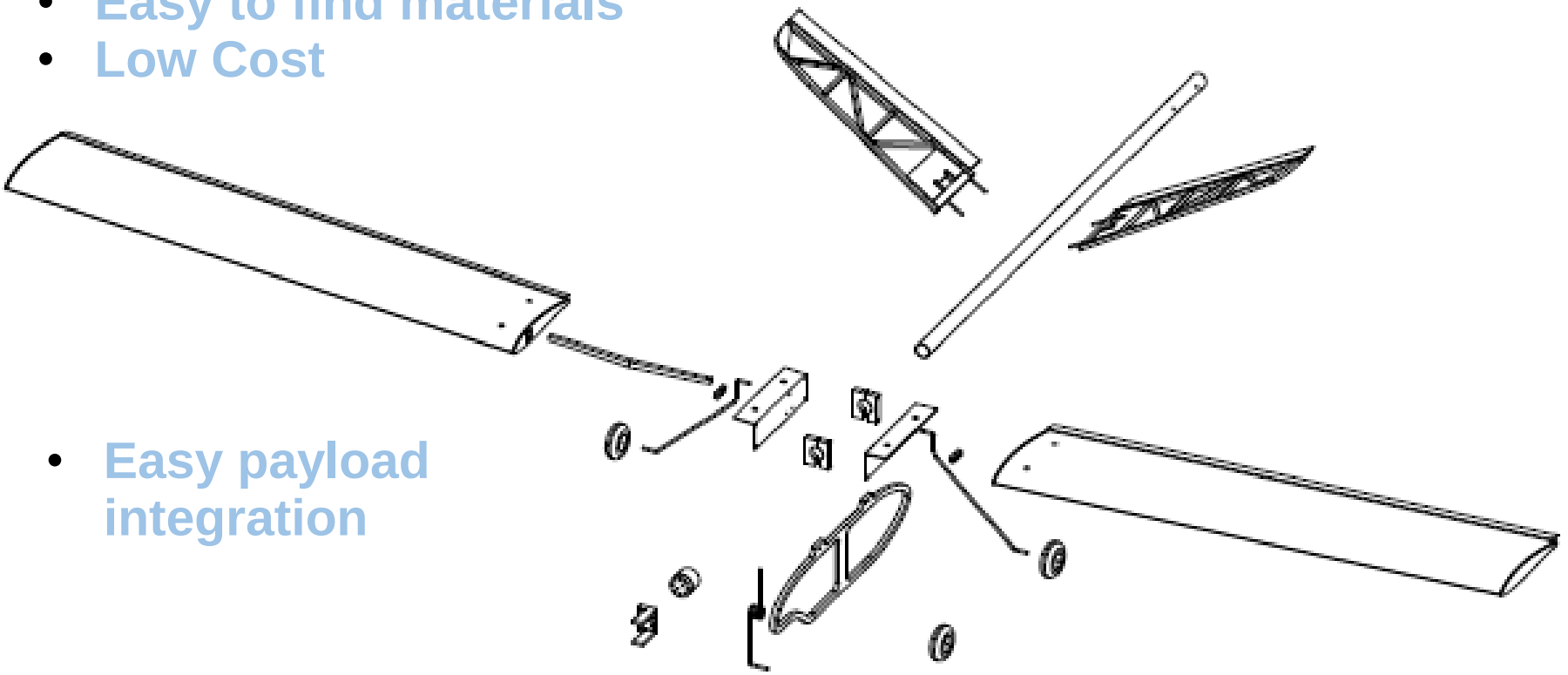
Ararinha

Open aircraft design developed at GISA - Interest Group on Unmanned Aerial Systems and Applications

Goal – share knowledge on unmanned aircraft and applications among students, industrial partners and hobbyists

Ararinha

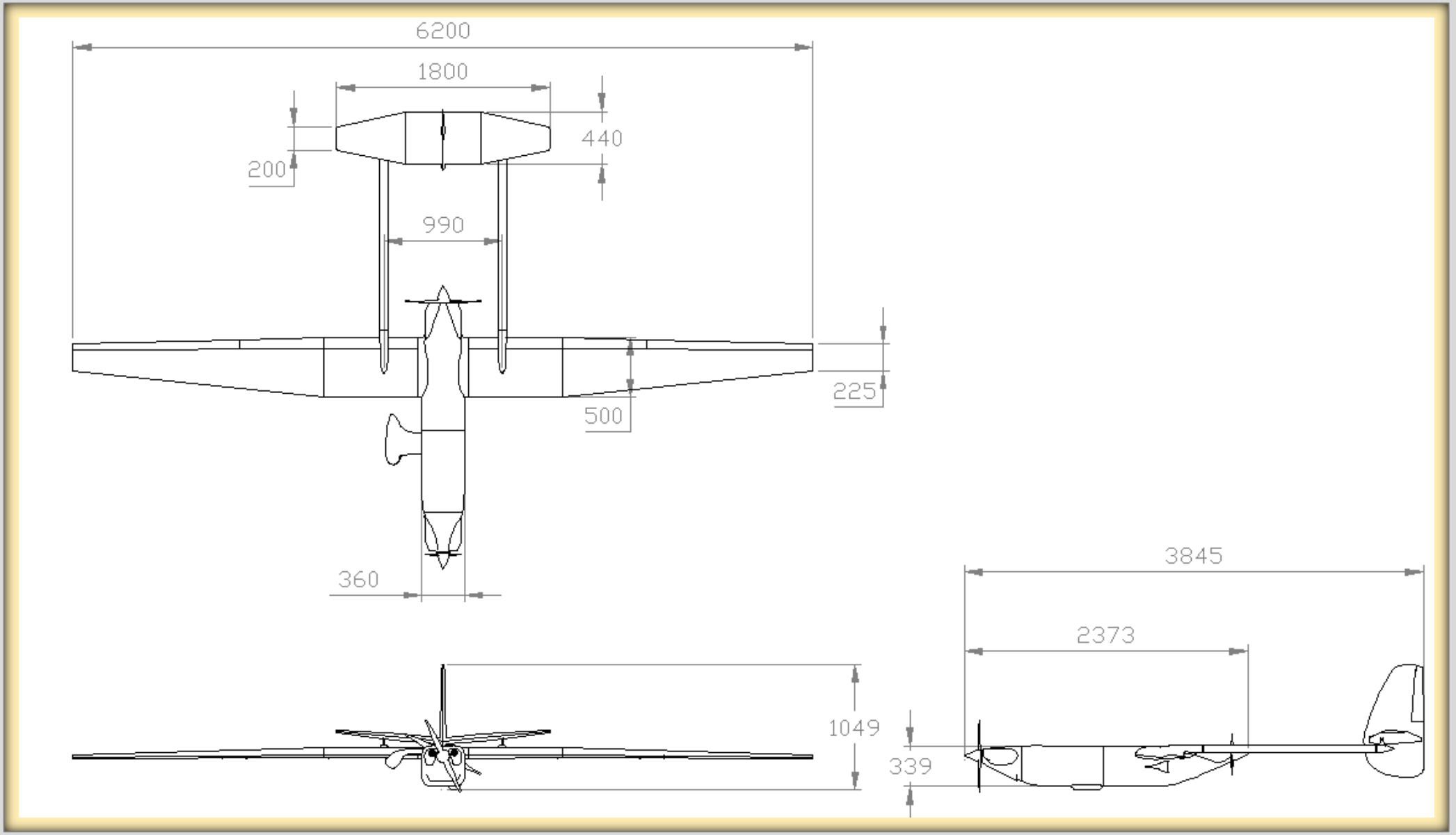
- Easy building
- Easy to find materials
- Low Cost



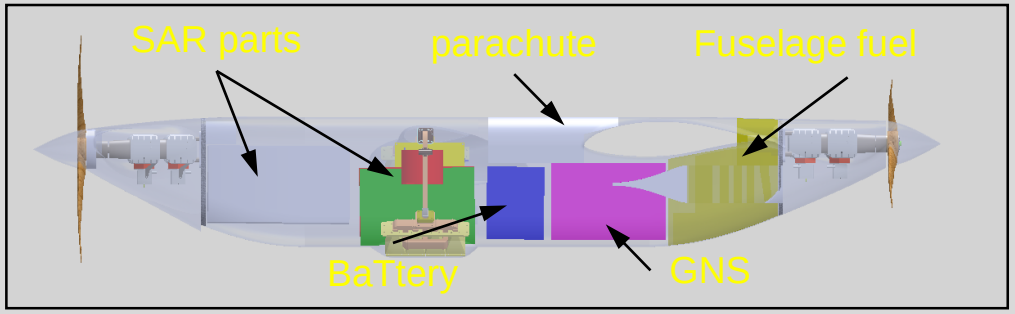
- Easy payload integration

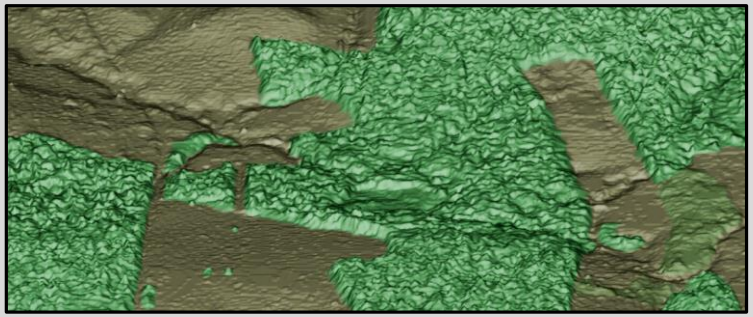
Orbisat-Aeroálcool SARVant

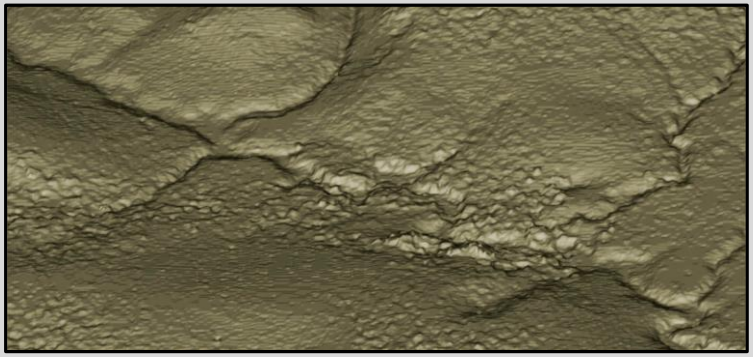
SARVant – Main Dimensions



SarVANT
Payload Integration







Tiriba MIL

- Electric propulsion
- Max takeoff weight: 7kg
- Payload: 800 g
- Autonomy: 90 min
- Cruiser speed: 70/100 km/h
- Stoll speed: 40/55 km/h

- Autonomous or remote controlled flight
- Landing – automatic parachute landing, manual belly landing
- Takeoff – automatic hand launch

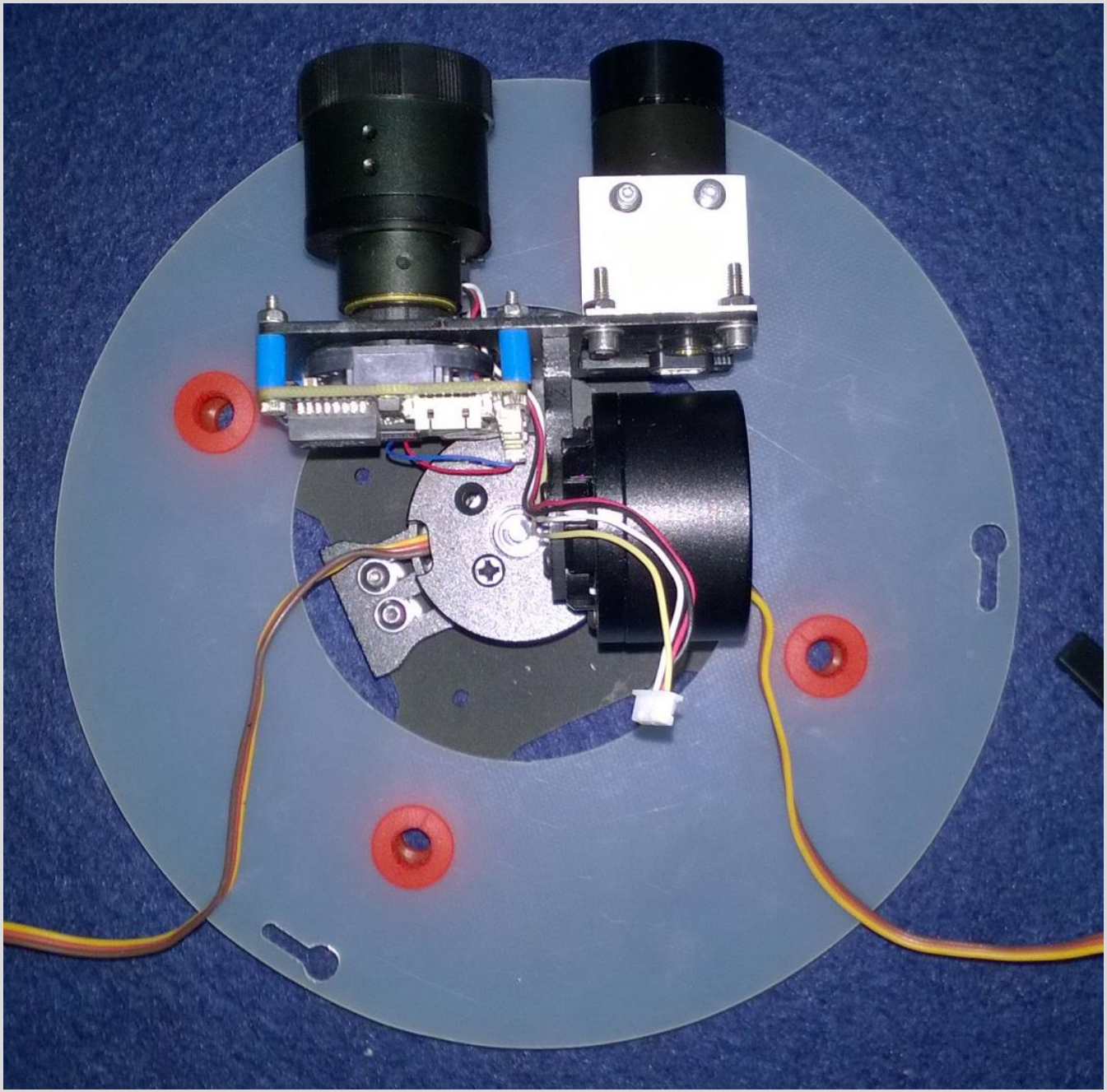
Tiriba MIL

Tiriba MIL

Tiriba MIL


12V/CARGA BAT
LIGA/DESLIGA
SOM
PARAQUEDAS
RETORNA
MODO DE VOO
COMUNICAÇÕES
TELA LCD
CONTROLE 1
LIMPA
CONTROLE 2
ENTRA
TIRIBA MIL
AGX Tecnologia
USP ICMC
CTEx

Tiriba MIL



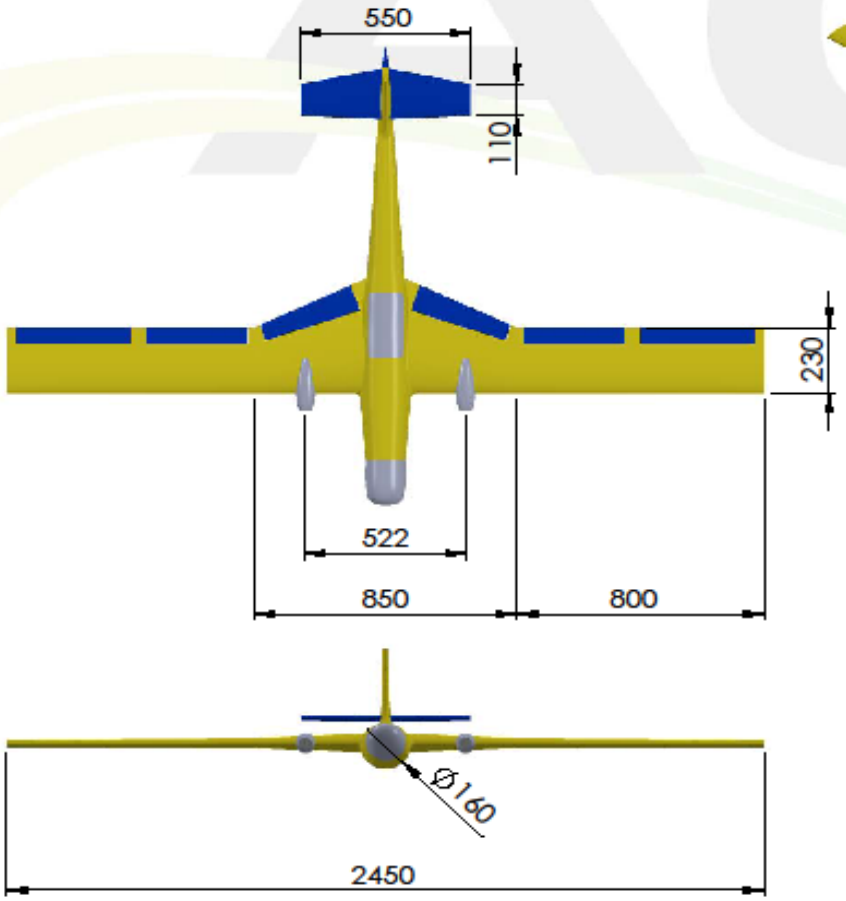
Tiriba MIL

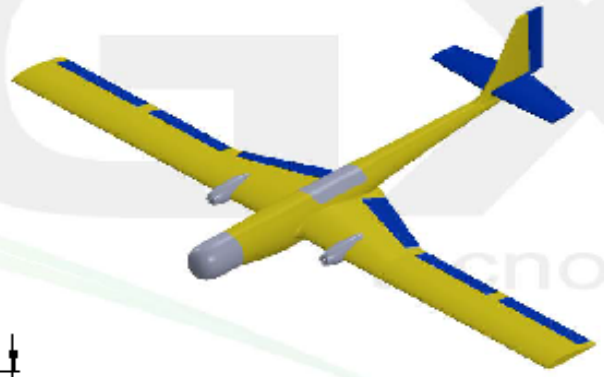
Tuim/Agilis

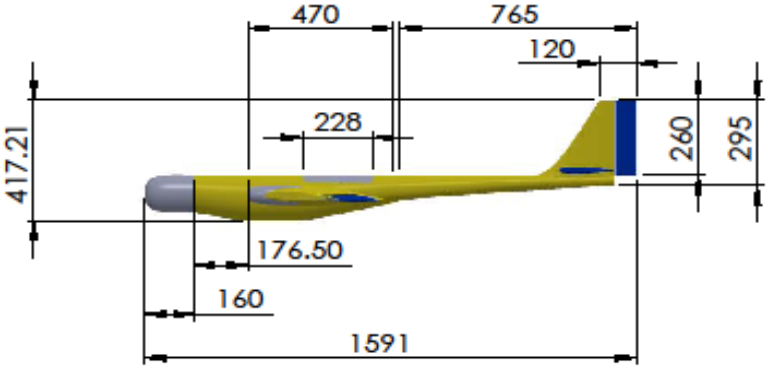
- MTOW: 7/9 Kg
- *Payload*: 1,5/1.8 Kg
- Cruiser: 100Km/h
- Autonomy:
  - 1h @ 80Km/h
  - 2.5h @ 100Km/h
- Propulsion:
  - Twin engine, electric powered
  - Gas – 35cc
- Takeoff/Landing: VTOL
- Emergency parachute

Tuim/Agilis

TUIM







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Applications
Agriculture Management

Applications
Agriculture Management

Precision Agriculture

1. **Data gathering**

   Remote sensing

   Local sensing

2. **Data analysis**

   Problem identification

   Opportunities identification for better crop yields

3. **Action**

   Raw data -> Thematic maps -> Actuation maps

   Temporal resolution is important

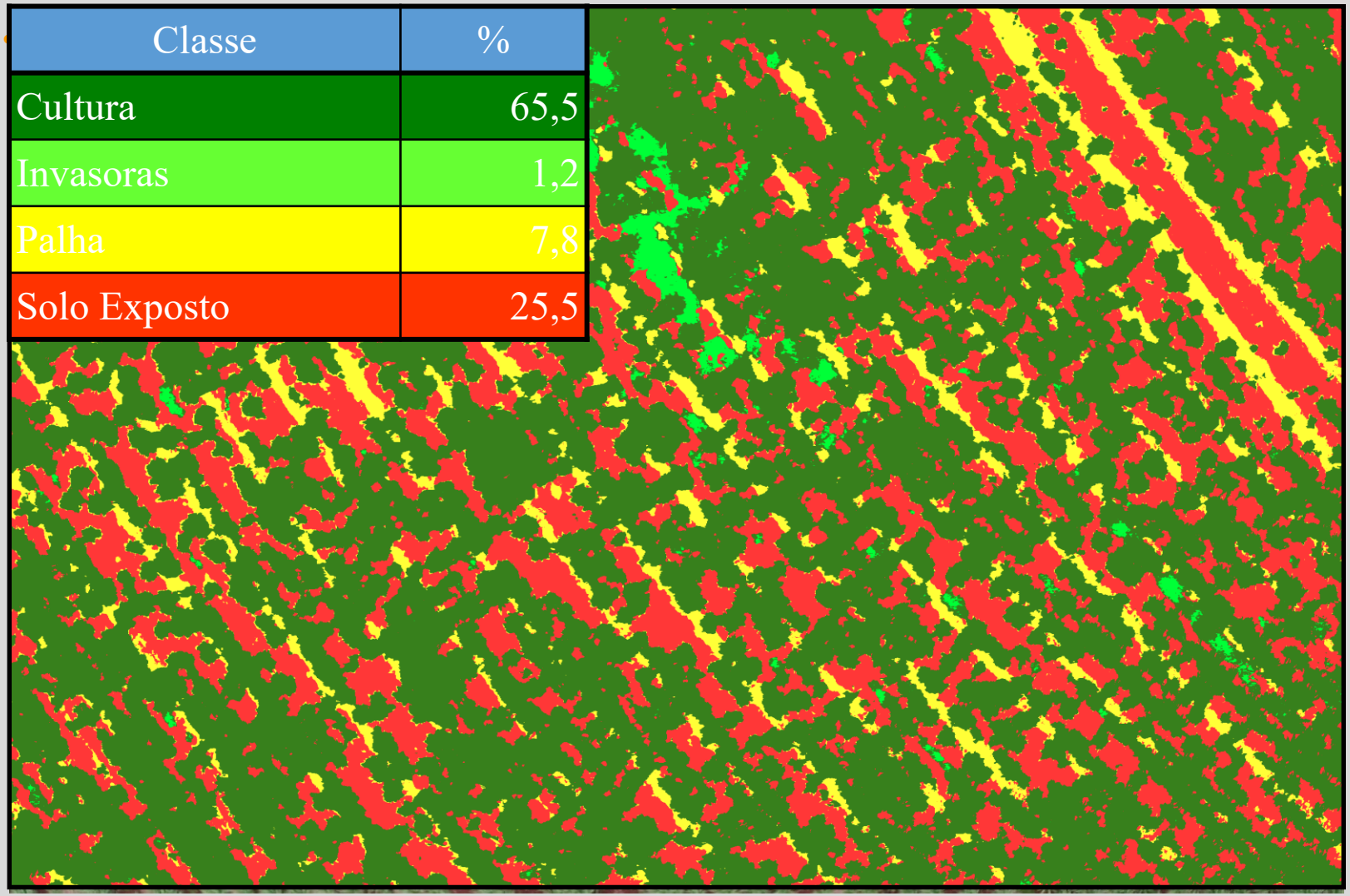
   Problem correction / opportunities exploration

   Current season / future seasons

Applications
Agriculture Management

Soil, Straw, Weed and Crop Mapping

Classe	%
Cultura	65,5
Invasoras	1,2
Palha	7,8
Solo Exposto	25,5

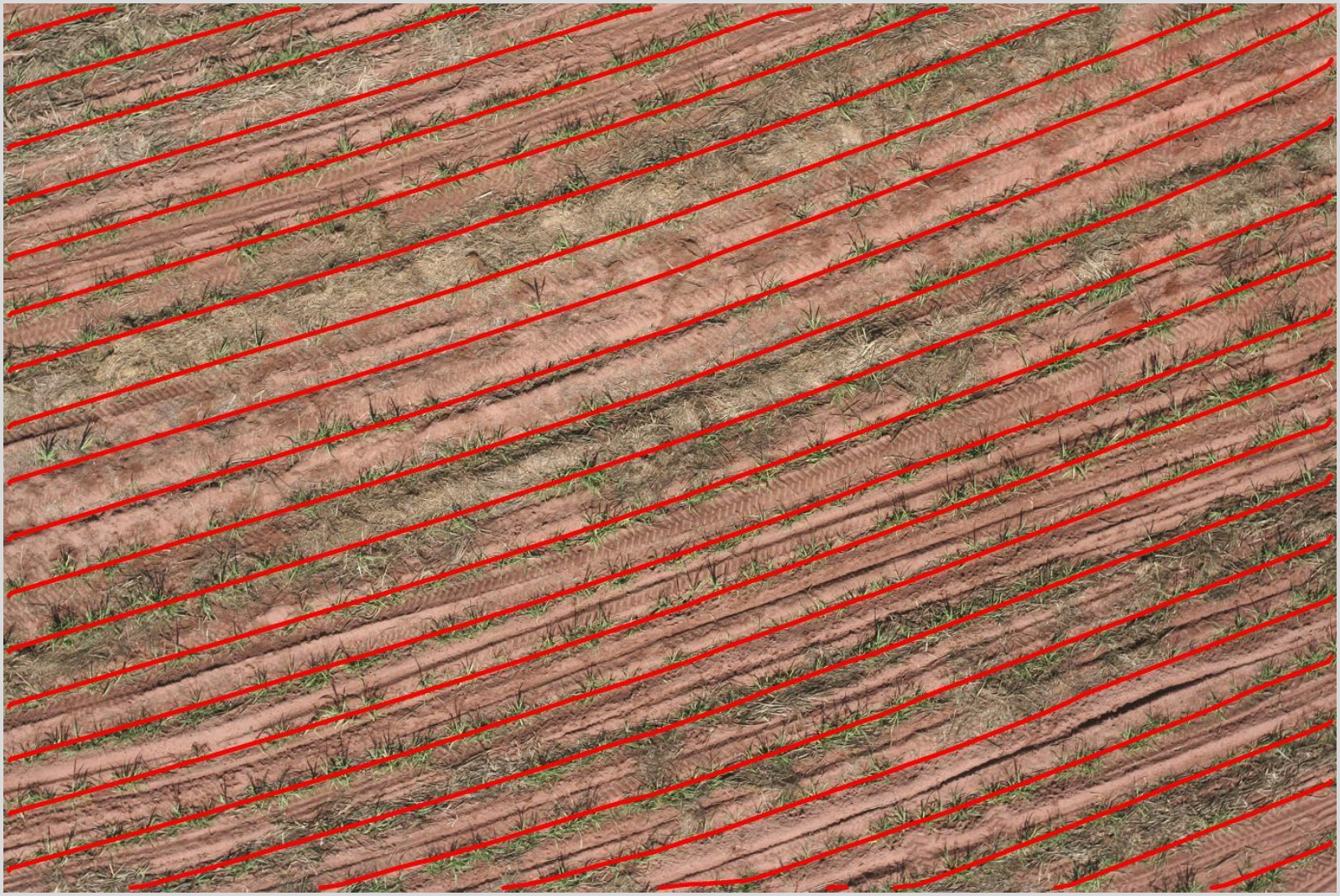


Applications
Agriculture Management

- Faults Mapping

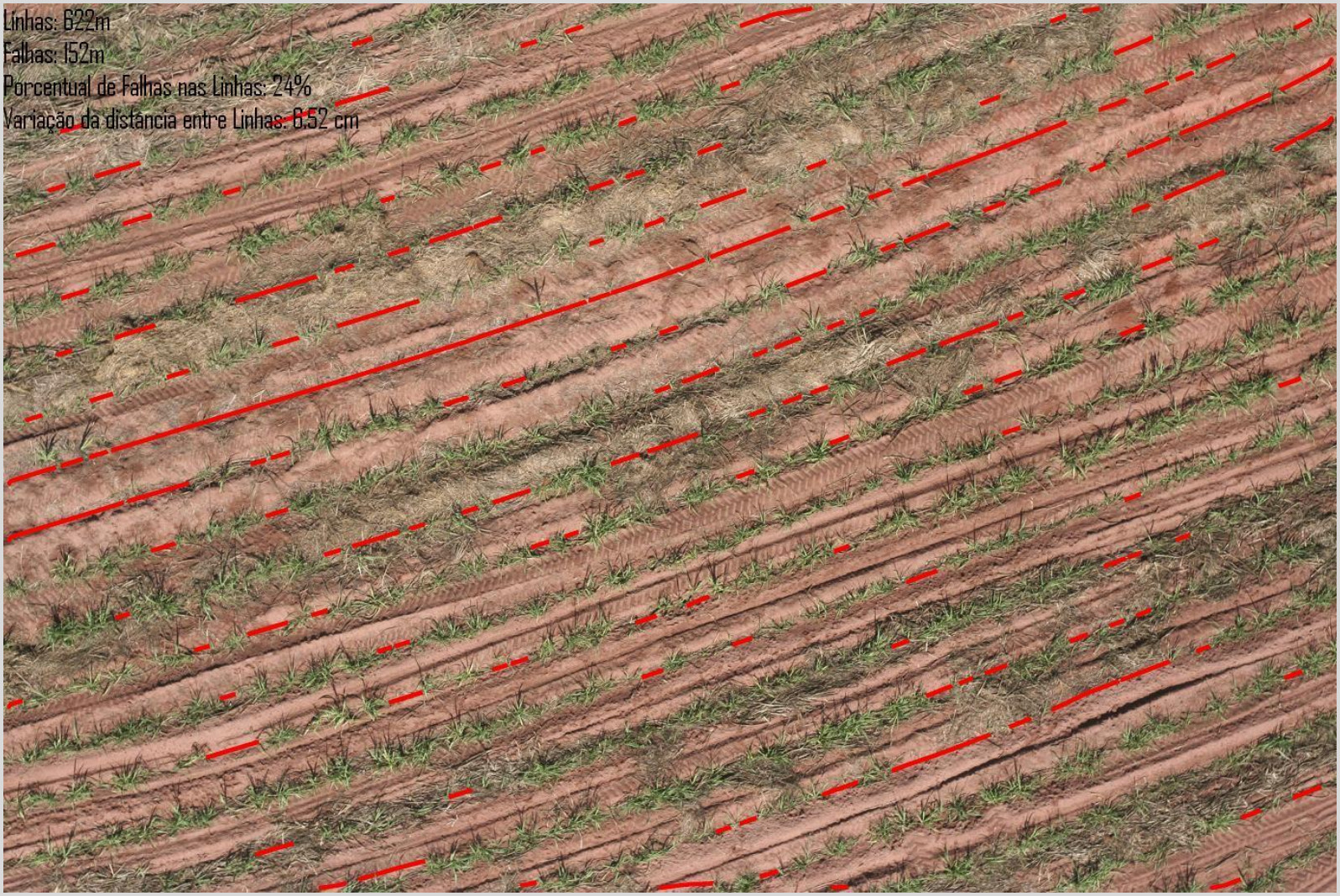
Applications
Agriculture Management

- Faults Mapping



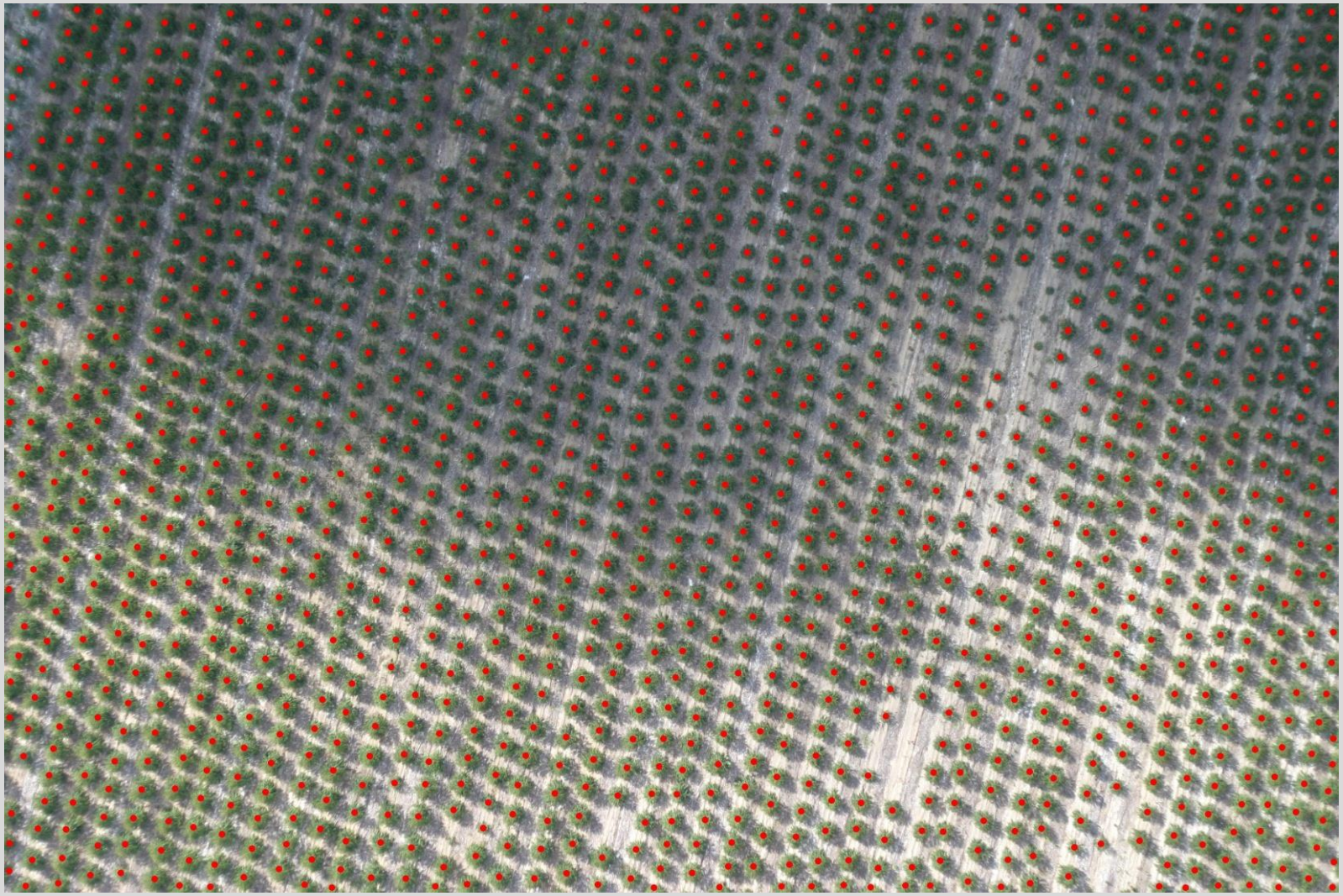
Applications
Agriculture Management

- Faults Mapping



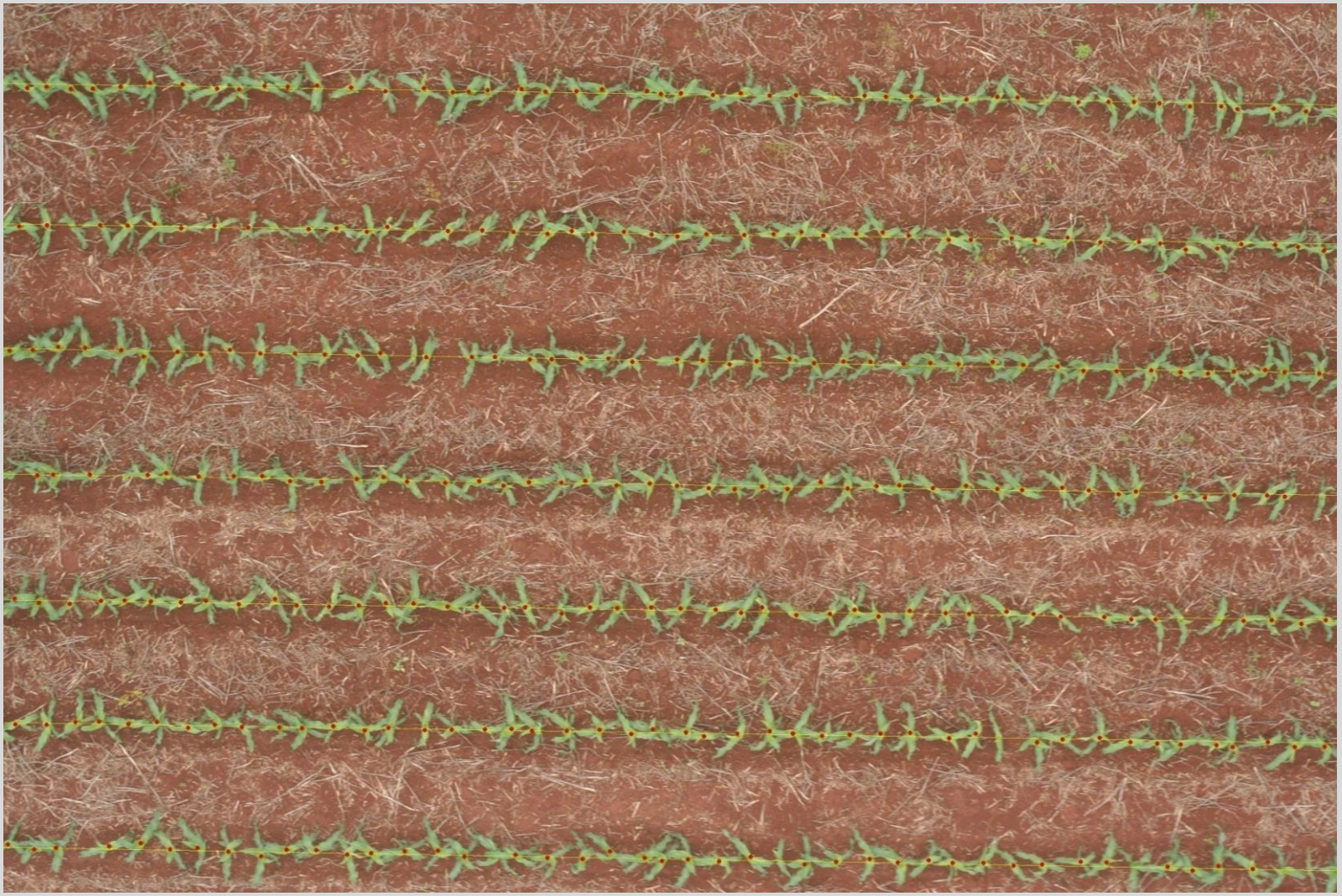
Applications
Agriculture Management

- Tree Counting



Applications
Agriculture Management

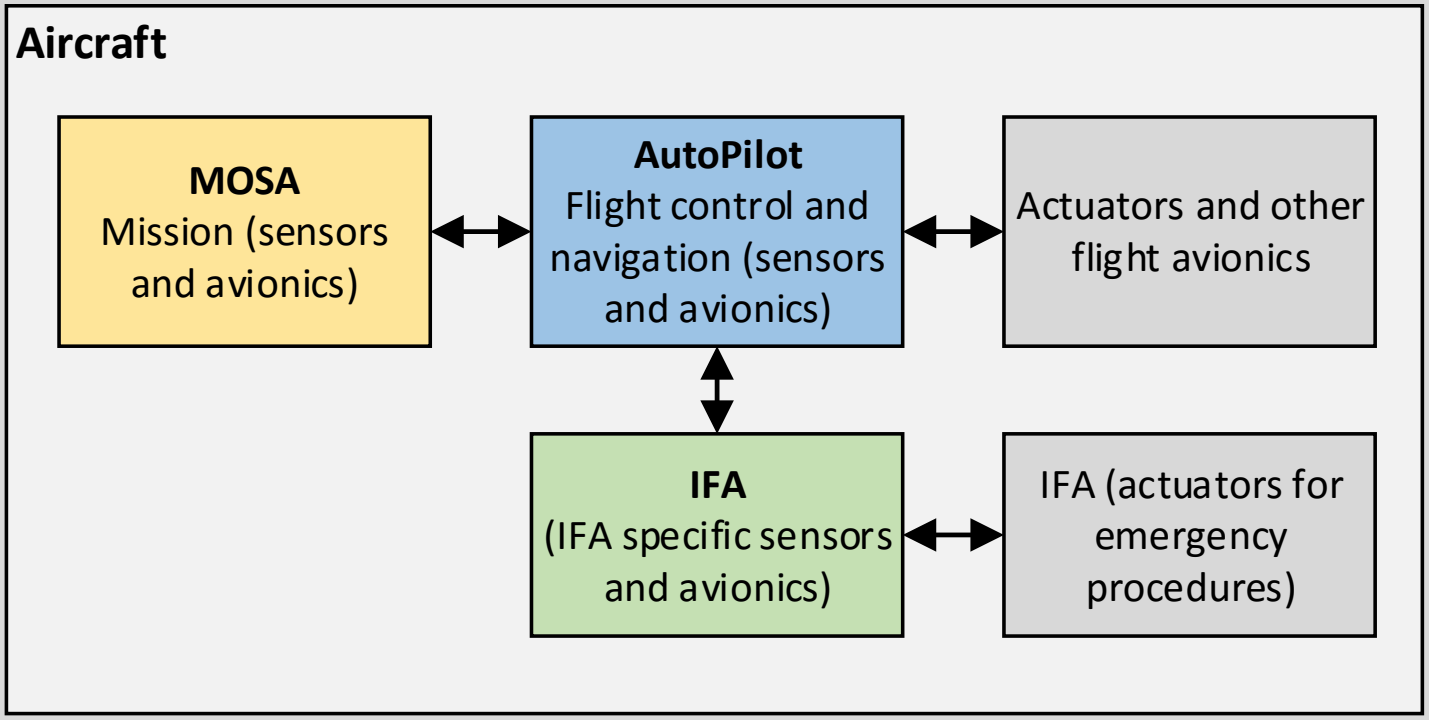
- Seeding Quality Evaluation



UAS Components

- Ground segment
  - Ground Monitoring and Control Station
  - Ground Payload Control Station
- Aerial segment
  - Aircraft
  - Control avionics
  - Payload
- Communications
  - Air-Air
  - Air-Ground

Improved System Organization



MOSA:

- Mission accomplishment

AutoPilot:

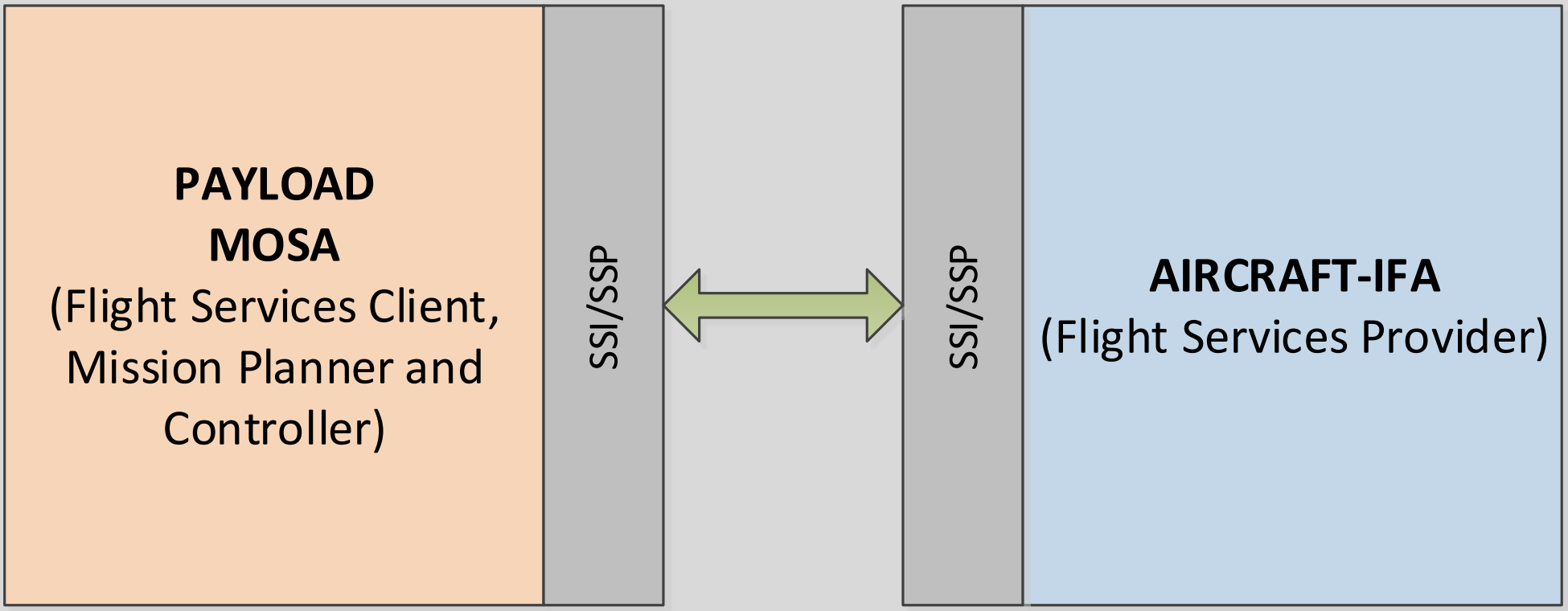
- Flight control
- Basic navigation
- Flight services
- Communication services
- Position services

IFA:

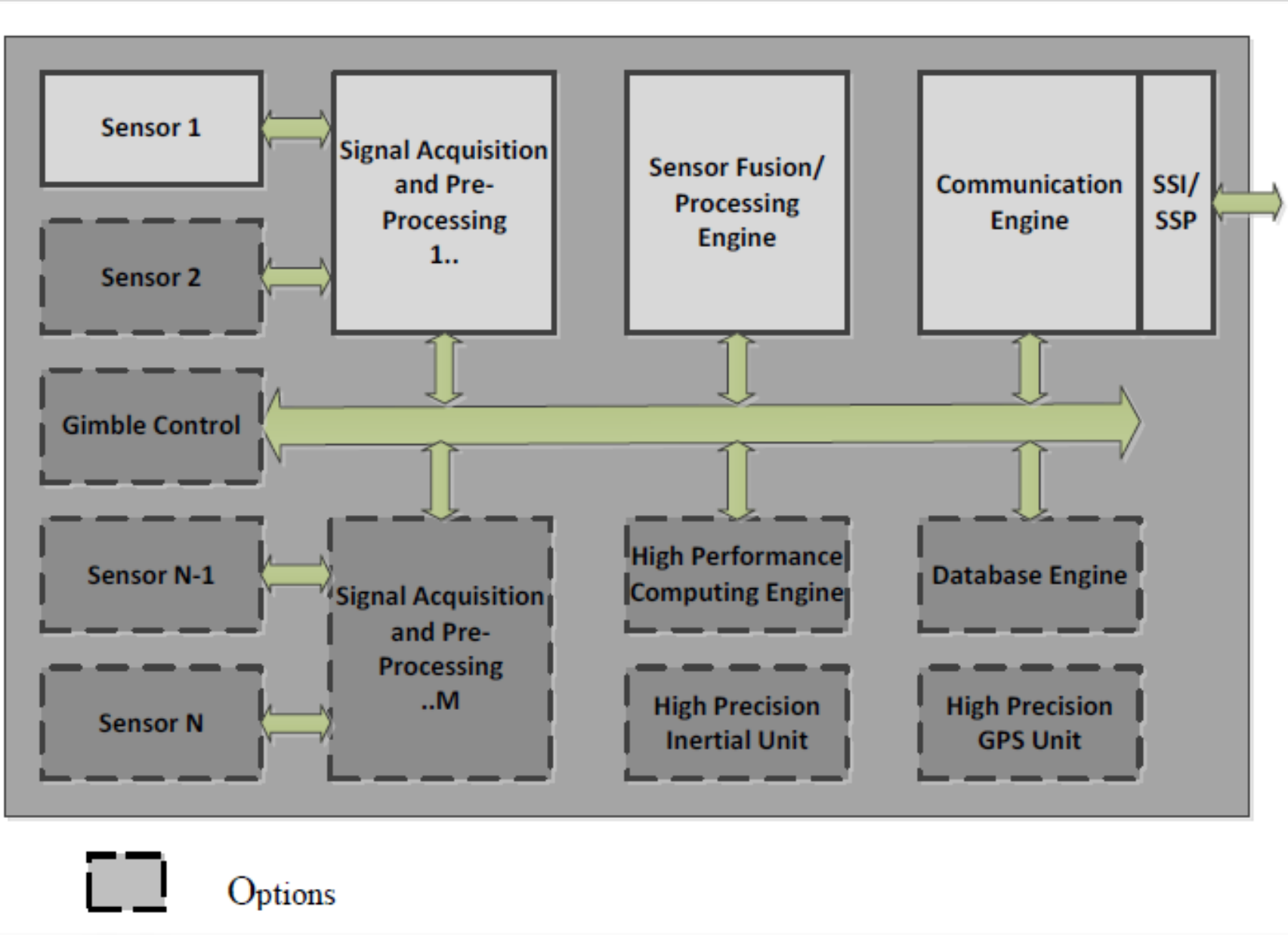
- Ensure Safety
- May provide safety-related information

Separating the Mission

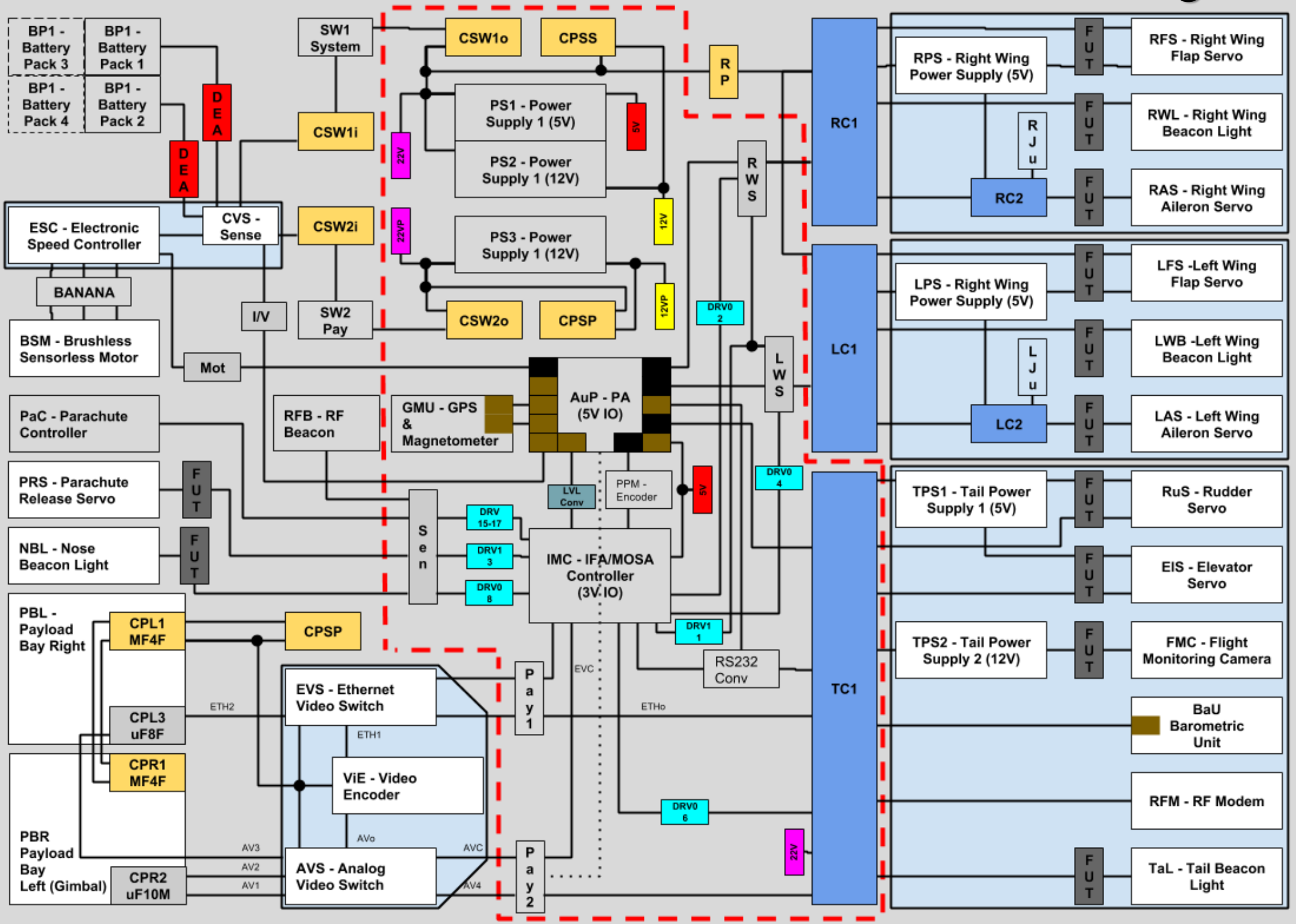
Mission Oriented Sensor Array



Functional Architecture of a MOSA System



Tiriba MIL – Block Diagram



Success Metrics

- Safety point of view – no catastrophic faults (no loss of human lives or costly installations)
- Mission point of view – full mission accomplishment
- Commercial point of view - Adequate Cost-Benefit ratio

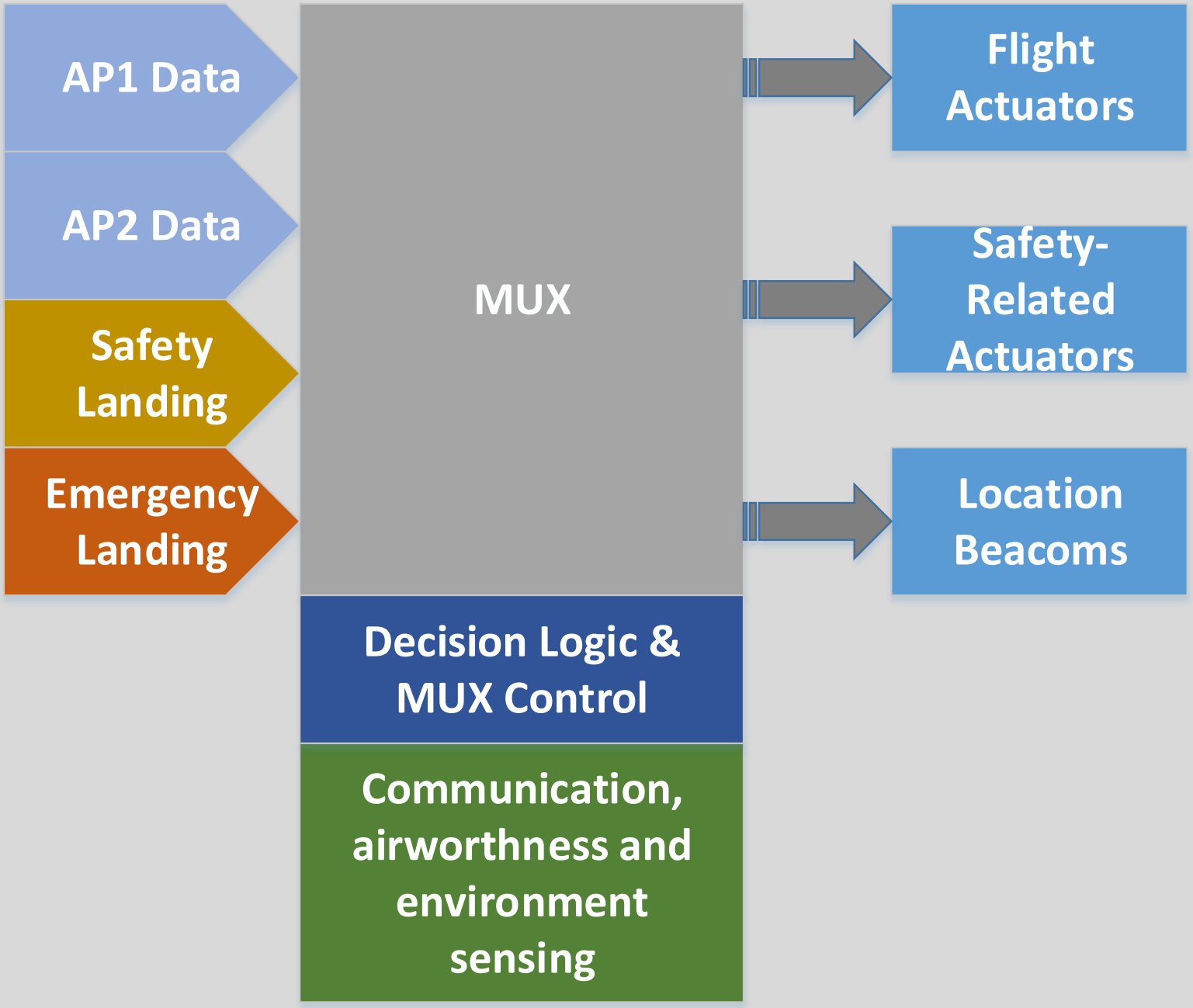
Failure Rates

- Catastrophic failures – lead to losses of human lives or hull loss
- Rates:
  - Commercial aviation – 10^{-6} per flight hour
  - Light Civil aviation – 10^{-4} per flight hour
  - Medium to big UAVs - 10^{-2} to 10^{-3}
  - Medium to big UAVs - 10^{-1} to 10^{-2}
- In fact, small UAVs only last for few tens of hours…

Cost Benefit

- Light civil aviation charges around R$700 per flight hour, including pilot, equipament, insurance, fuel, maintenance, depreciation, etc.
- A small UAV that lasts for 20 hours must cost less than:
  - R$20*700 (cost of 20 flight hours in a light aircraft) – R$20*100 (operator cost) = R$12.000
  - To present the same cost/benefit ratio of the manned aircraft…
- Solution
  - increase UAV robustness
  - decrease price
  - Increase automation

In the Rexcue - IFA^{2}S System



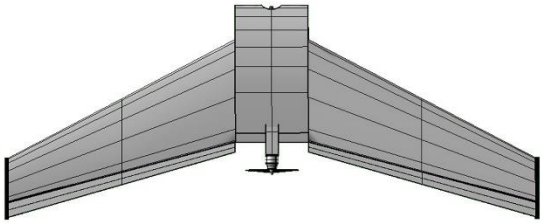
Low Cost, Professional Small UAVs

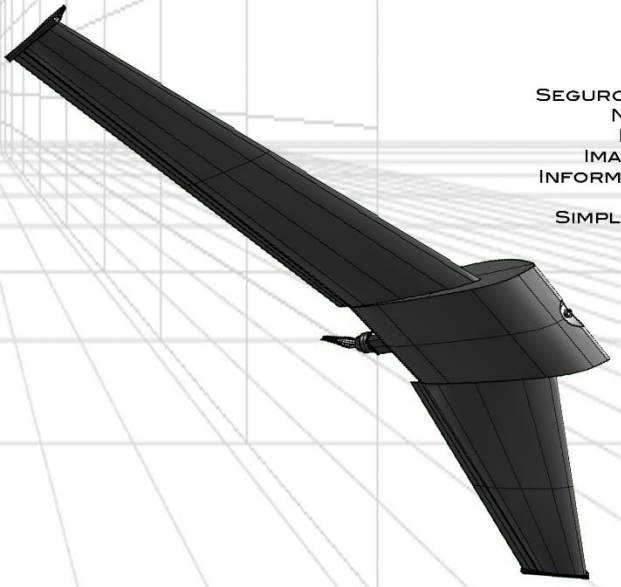
	Carcará 1	Ararinha Gas	Agilis Gas
Availability	Since 2006 (Brazilian Navy)	Since 2013 (Improved from a open project)	2016 (VTOL capability, single or dual engine)
Wingspan	1,6m	1,9m	2,45m
Powerplant	Gas, Ethanol, Methanol, Electric	Ethanol (option: Gas, Methanol, Electric)	Gas (option: Electric)
Endurance	50min	75 min	150min
Takeoff (Automatic)	Hand launching or catapult	Hand launching or tricycle	Hand launching, or VTOL
Landing (Automatic)	Deep Stall	Tricycle, parachute, belly, floats or deep stall	Parachute, skis or VTOL
MTOW	1,5Kg	3,5Kg	9Kg
Payload	250gr	750gr	1800gr
Cruiser speed	45 Km/h	70 Km/h	90 Km/h
Structure materials	Foam, carbon fiber	Aluminum, foam, wood	Carbon/glass fiber

SANTOS LAB

Carcará RPV

O sistema aéreo Carcará RPV representa uma solução de baixo custo para missões de reconhecimento tático em tempo real. Esse robusto sistema está atualmente em operação na Marinha do Brasil onde equipa o primeiro pelotão de veículos aéreos não tripulados das forças armadas brasileiras, PelVANT.





Características do sistema

baixa assinatura acústica
Seguro para operar sobre área urbana
Necessita de apenas um operador
Rápida montagem e desmontagem
Imagens transmitidas em tempo real
Informações Atualizadas de Telemetria

Simplicidade portabilidade e robustez

www.santoslab.com

Carcará 1

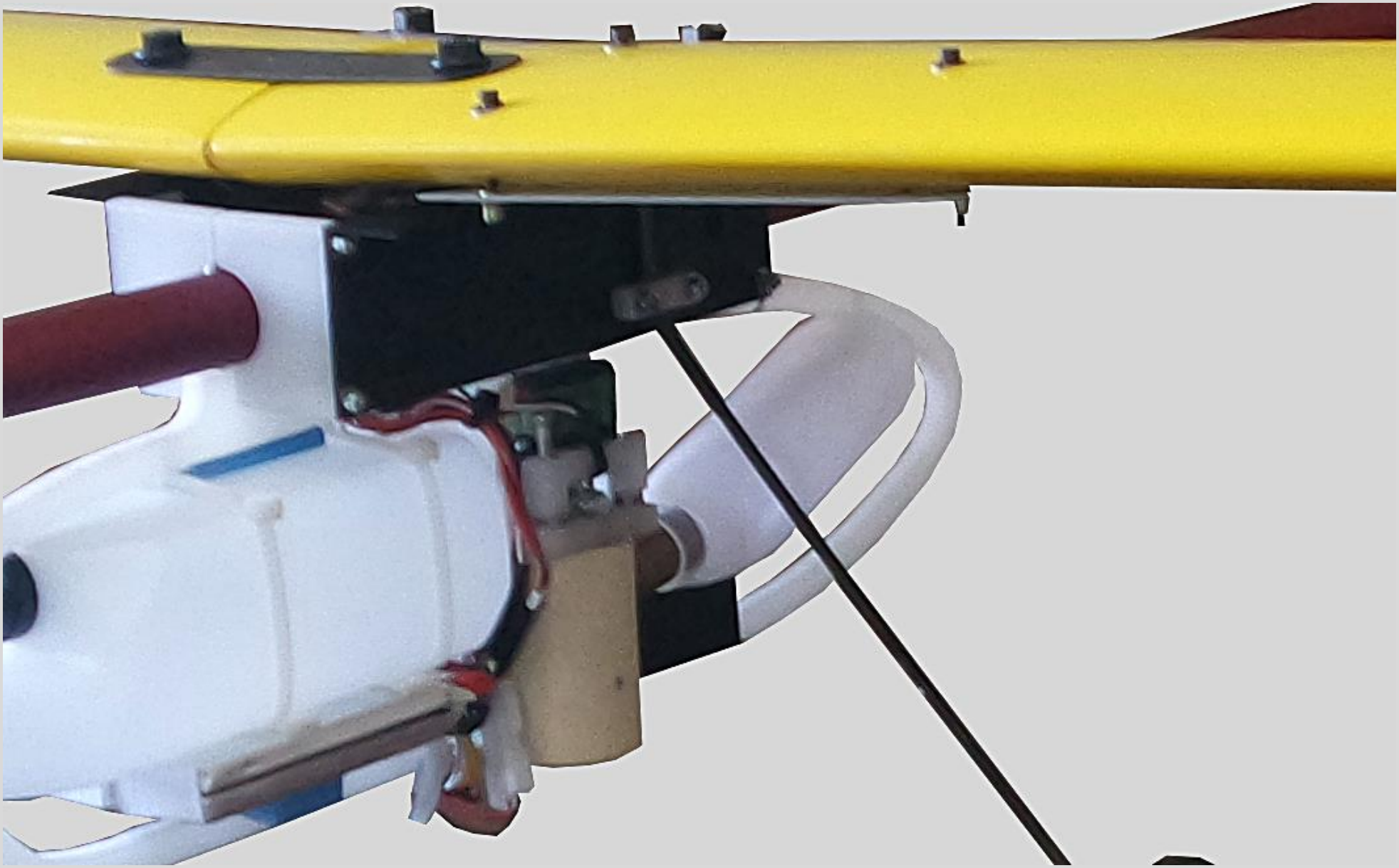
Since 2006 (Brazilian Navy)
1,6m
Gas, Ethanol, Methanol, Electric
50min
Hand launching or catapult
Deep Stall
1,5Kg
250gr
45 Km/h
Foam, carbon fiber


Carcará 1

Ararinha Pro

Ararinha Gas
Since 2013 (Improved from a open project)
1,9m
Ethanol (option: Gas, Methanol, Electric)
75 min
Hand launching or tricycle
Tricycle, parachute, belly, floats or deep stall
3,5Kg
750gr
70 Km/h
Aluminum, foam, wood

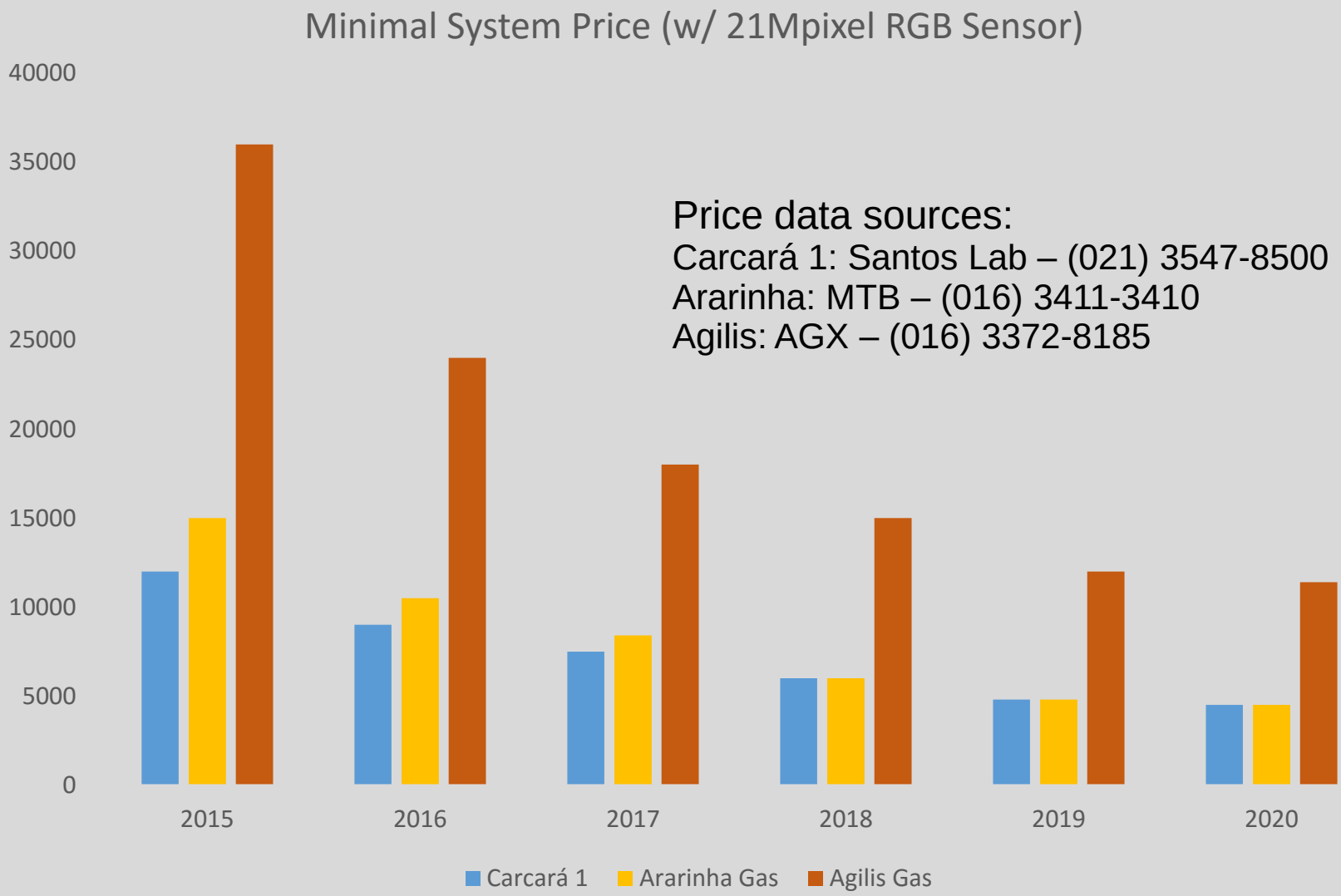
Dispenser



Low Cost, Low Weight Sensors

Sensor Type	Spectrum	Spatial resolution	Weight	Price – US$
Photographic Camera Small	Visible - RGB	21 Mpixels	250gr	400
Photographic Camera Small	Visible - RGB	29 Mpixels	350gr	600
Photographic Camera Medium Size	Visible - RGB	36 Mpixel	550gr	2000
Photographic Camera Full Frame - Big	Visible - RGB	51 Mpixel	1050gr	3700
Video camera	RGB	4Mpixel	20gr	200
Multispectral camera	R, G, NIR	3Mpixel	200gr	?
Thermal vídeo camera	8000 – 12000 um	O,25Mpixel	35gr	3000
Multispectral camera	4 to 12 bands	0,1Mpixel	500-1200gr	?

The Good News
Small UAVs Price Evolution in Brasil (R$)



Price data sources:
Carcará 1: Santos Lab – (021) 3547-8500
Ararinha: MTB – (016) 3411-3410
Agilis: AGX – (016) 3372-8185

Final Remarks

- Main expertise in UAV technology
  - Aircraft design
  - Aircraft manufacturing
  - Development of electronic control systems (hardware and software)
  - UAV field operation experience

- Focus on
  - Intelligent flight (IFA) controlled by intelligent sensors (MOSA)
  - Quality assurance and certification
  - Commercial applications, mainly in agriculture and environment monitoring
  - Favorable cost/benefit ratio

Thank you!