Best practices for successful lean satellite projects

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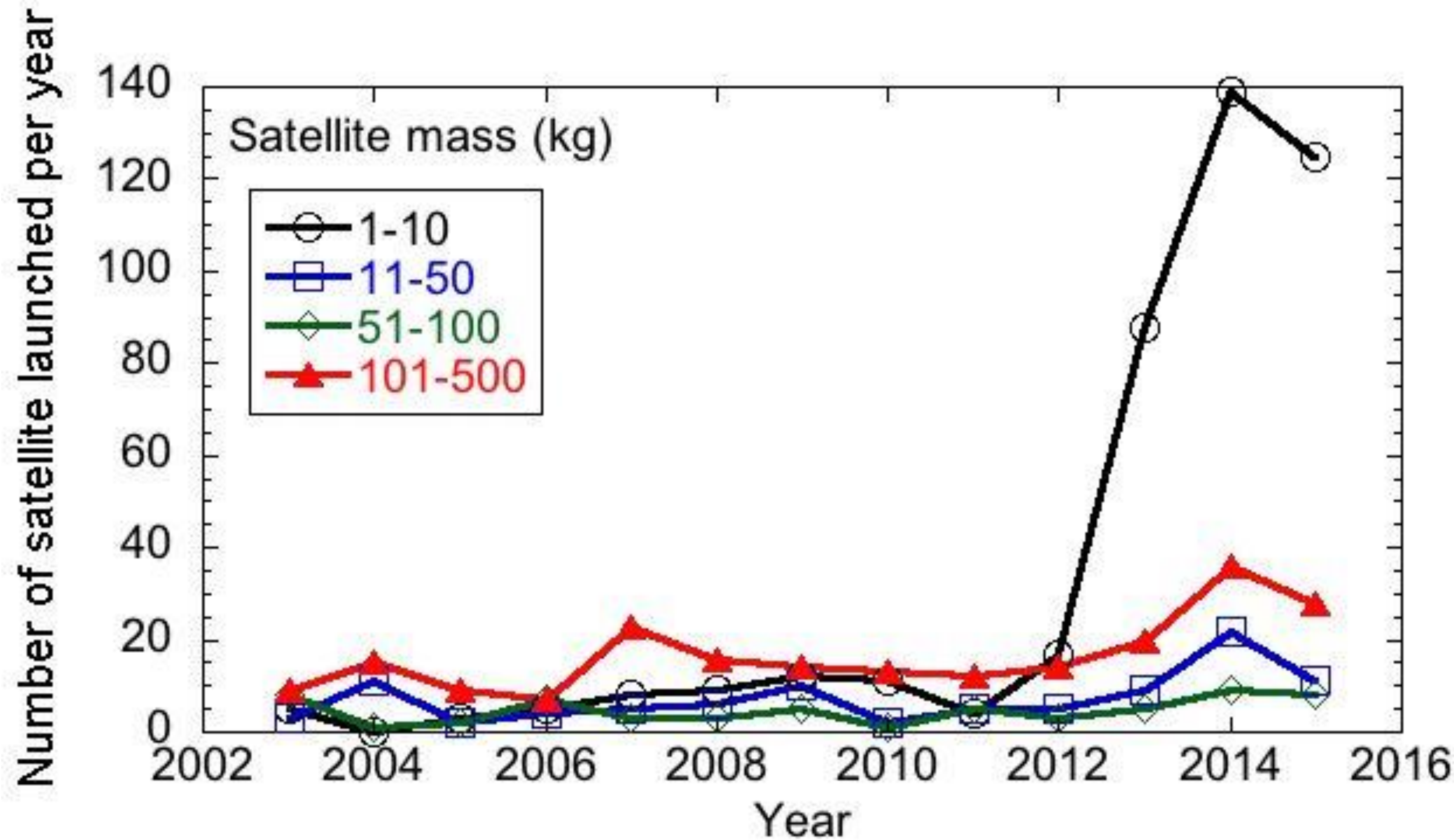
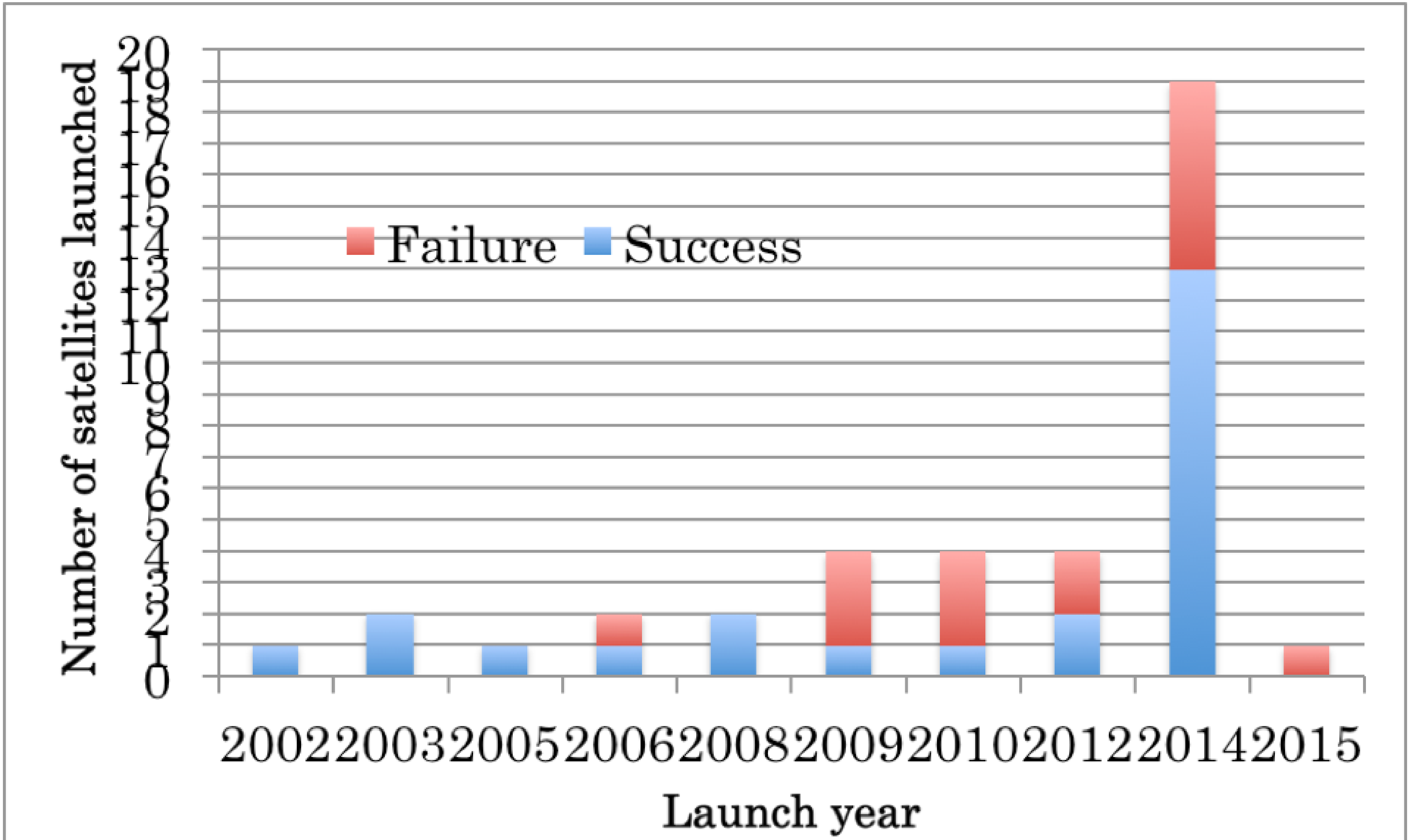
Worldwide launch trend of small/micro/nano/pico satellites



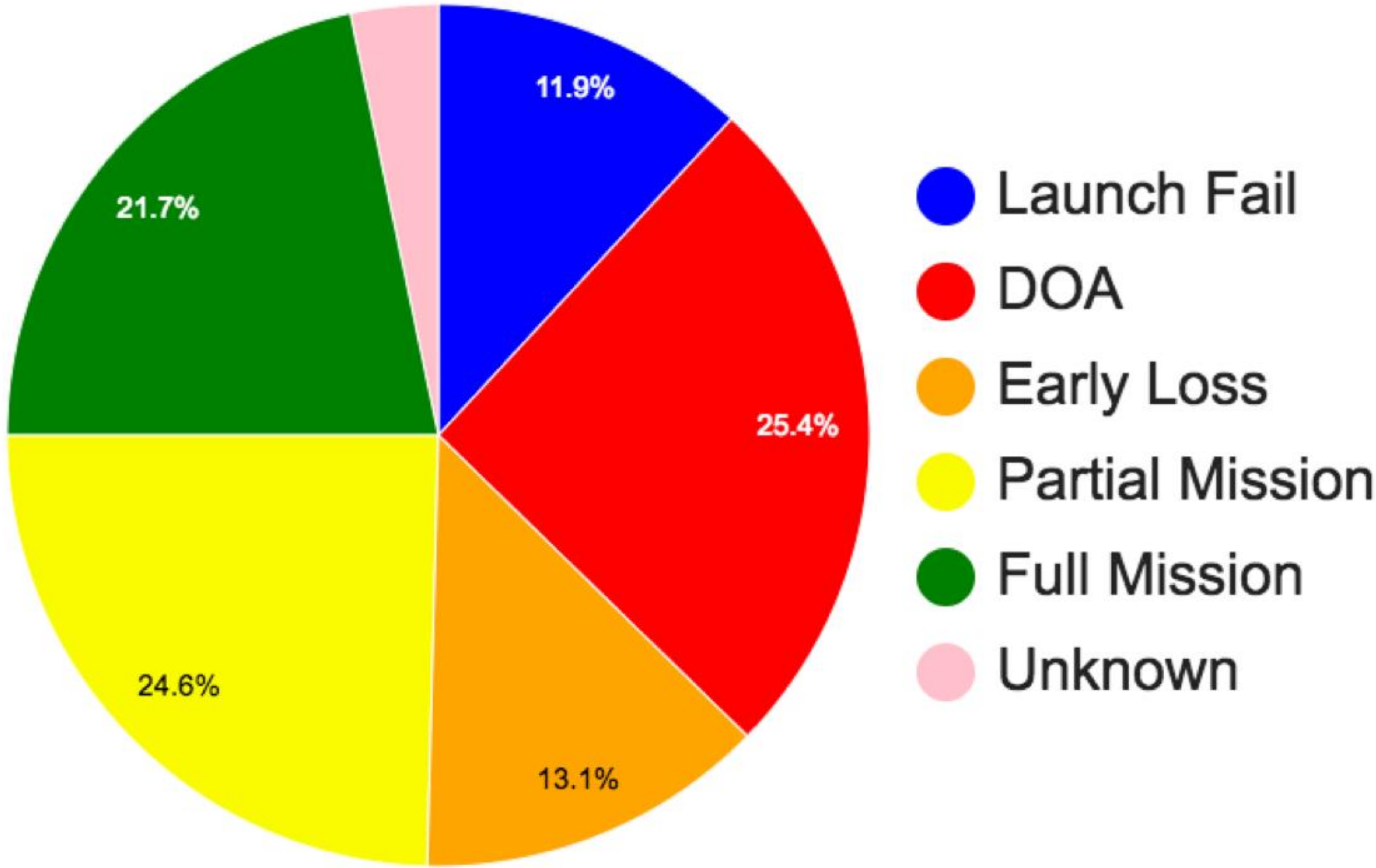
Source: Kyushu Institute of Technology

Success and failure of Japanese university satellites



Source: Kyushu Institute of Technology

Mission Status for all University-Class Missions up to 2016

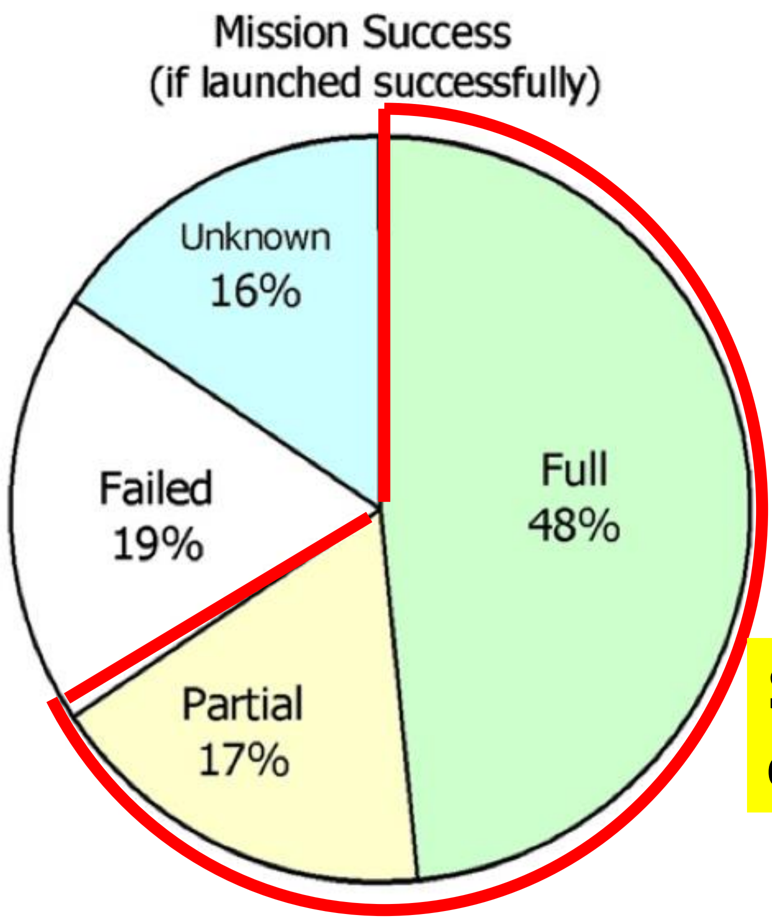


Sourcec: University-Class Spacecraft by the Numbers: Success, Failure, Debris. (But Mostly Success.)
By Michael Swartwout, Clay Jayne, Small Satellite Conference 2016

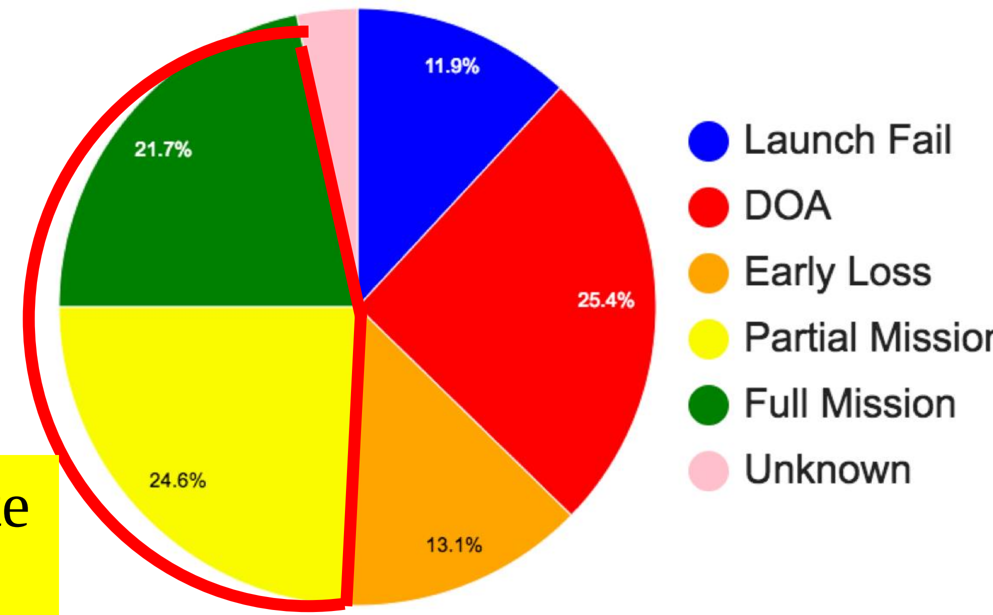
25% does not give even radio signal（DOA: Dead on arrival)
Approximately 50 % failure rate

Improving?

up to 2009



up to 2016



Success rate decreases

CubeSat

Survey of worldwide pico- and nanosatellite missions, distributions and subsystem technology, by J. Bouwmeester, J. Guo, Acta Astronautica 67 (2010) 854–862

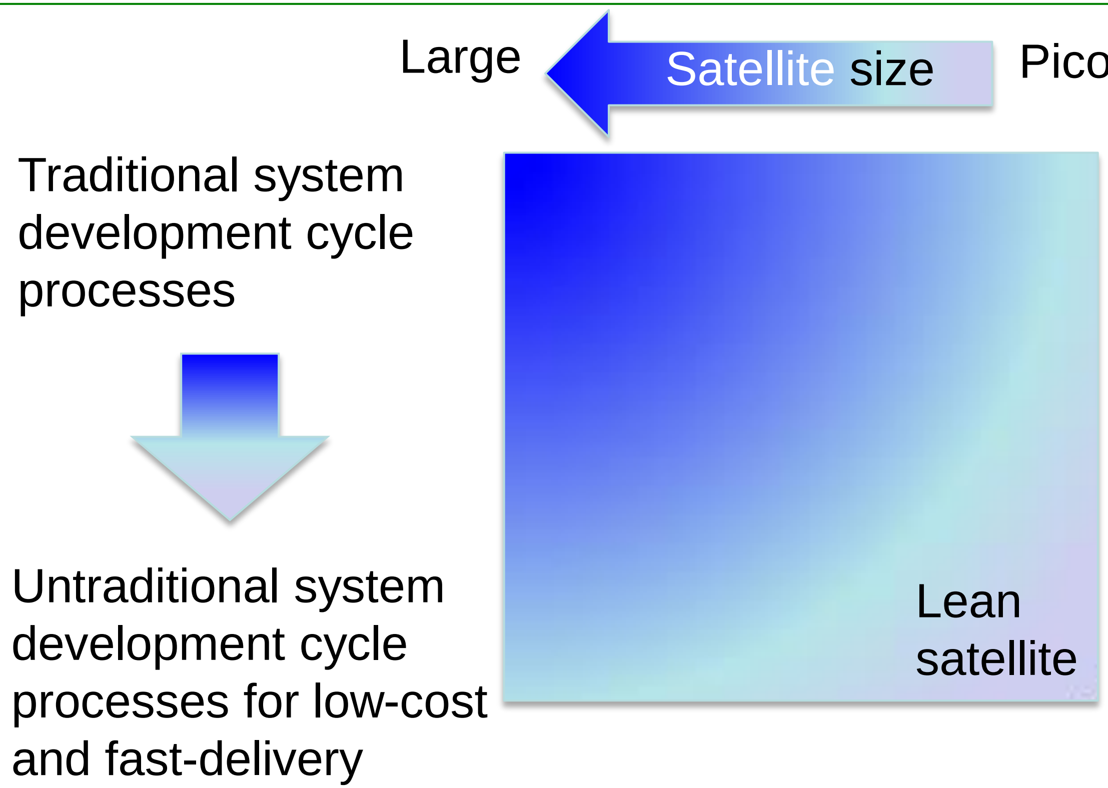
Success rate actually decreases

Up to 10kg

Because of new-comers?

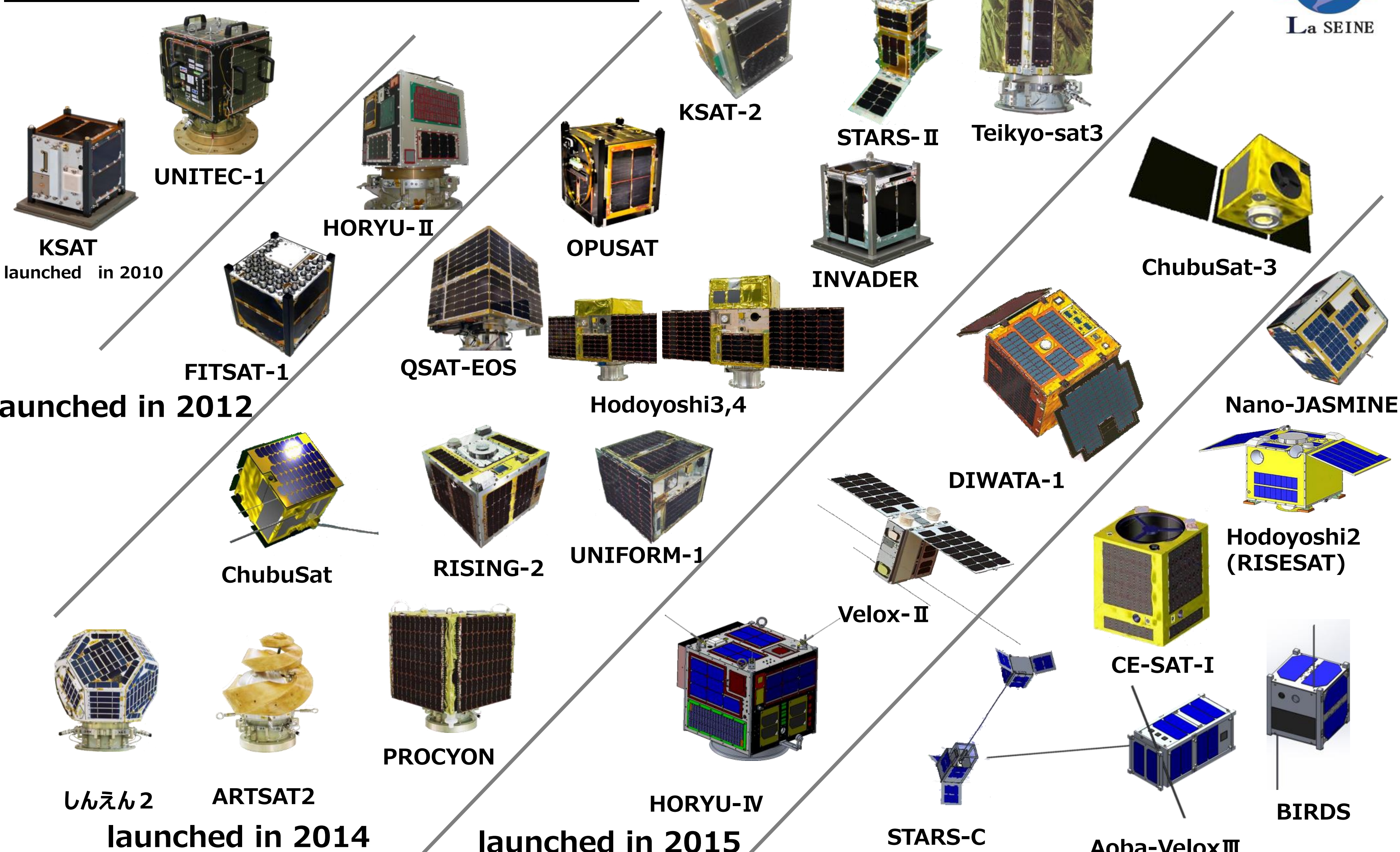
Lean satellite

A lean satellite is a satellite that utilizes non-traditional, risk-taking development and management approaches – with the aim to provide **value** of some kind to the customer at low-cost and without taking much time to realize the satellite mission.



When we adopt untraditional development processes to achieve low-cost and fast-delivery, the size becomes inherently small

Kyutech satellite testing record



Two-thirds of less-than-50kg Japanese satellites

To be launched.

Introduction

- Witnessed many satellites failed at the very early stage in orbit
- The root cause of the failure often unknown due to limited amount of telemetry data before the failure
- Immature workmanship and insufficient verification are some common aspects in the failed project, especially in university projects
  - Issues of project management/systems engineering rather than technical issues
- There are also satellite projects that are carried out under tight budget and schedule, but achieve their mission
- What divides a successful project from a failed project?

Purpose

- Present the best practices for a successful lean satellite project, especially a university satellite project, based on the interview and our own experience at the testing center

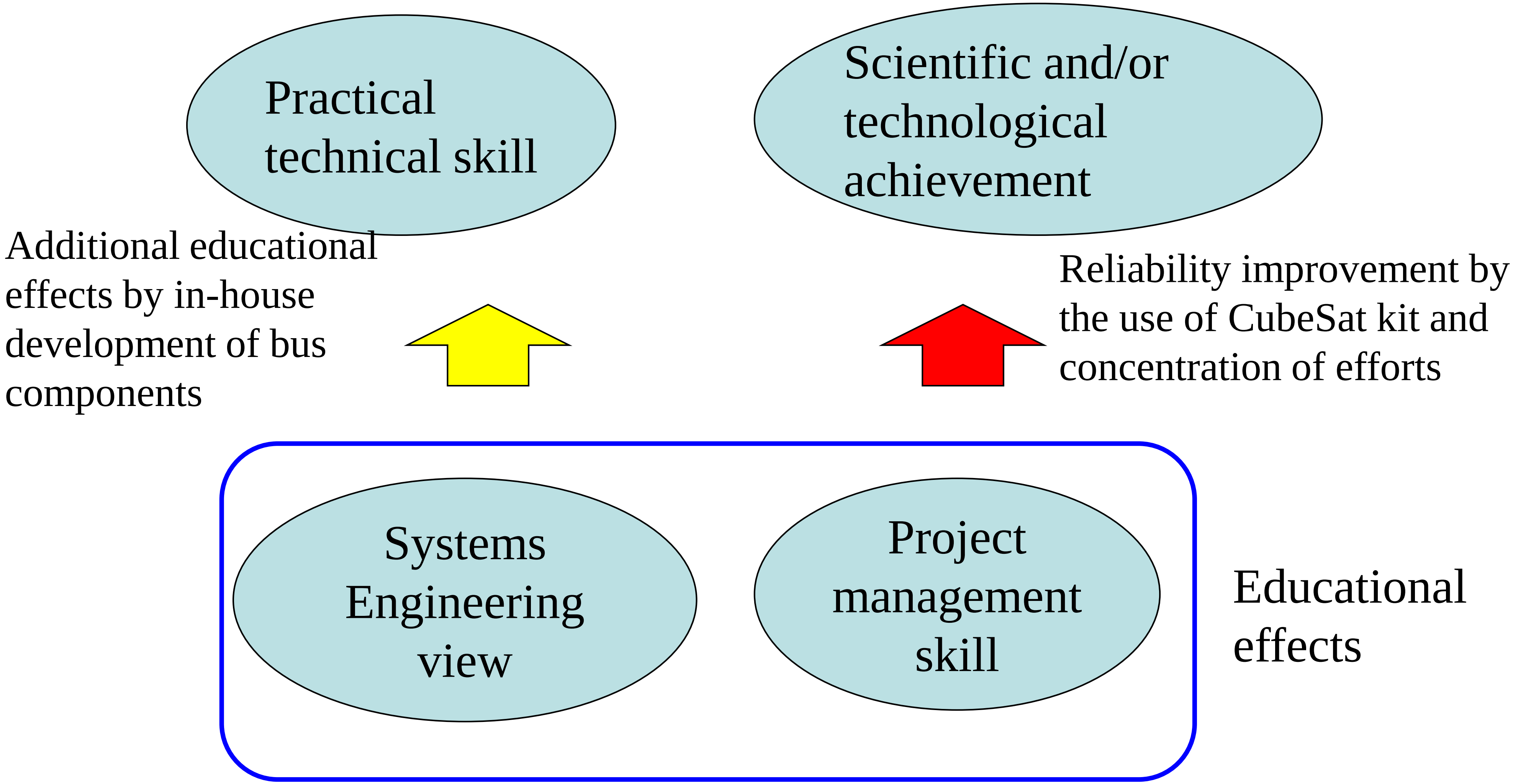
University satellite missions

1. Demonstration of missions specific to lean satellites
   – Earth imaging, Store & Forward, Constellation, etc
   – Mission itself is challenging and accept failure
2. Demonstration of new space technology that may be applicable to any class of satellites
   – Tether, radiation measurement, high voltage technology, etc.
   – Should focus on mission payload development using bus components with heritage
3. Student education
   – Learning "systems engineering view", "project management skill" and "practical technical skill".
   – The first satellite often fails, but the second satellite is improved

Current status of lean satellites

- Practical application via constellation started
  - Mass (?) production era?
- CubeSat gets larger
  - Shifting to 3U, 6U
- Mission is shifting to “Tech-demo”, “Science” and “Practical (commercial) application” from “Mission demonstration” and “Education”
  - University satellites are now required to improve reliability
- Frequent use of COTS components or CubeSat Kits provided by manufacturers (e.g. Gomspace, Pumpkin, etc.)
  - Focusing more on mission payload development rather than in-house development of bus components

CubeSat kit for university satellites



- If the purpose is not education, CubeSat kit should be used more aggressively

Surveys conducted so far

1. Lean satellite environment testing by domestic satellite developers (2011)
2. Application of COTS parts and technology in lean satellites (2014~)
3. Best practice to improve lean satellite reliability (2015~)
4. IAA Study on Definition and Requirements of Small Satellites Seeking Low-Cost and Fast-Delivery(2014 ～)

Lean satellite environment testing by domestic satellite developers (2011)

- Interviewed domestic lean satellite developers (15 groups, 18 satellites)
  - Early generation of Japanese lean satellites
- Tests effective to detect defects
  - Vibration, Thermal vacuum, End-to-End test
- Made multiple models (EM, FM, etc)
- Only 3 satellites did single event test
  - Difficult access to test facility
  - Limited know-hows of test method
- Anomaly causes in orbit
  - Power
  - Attitude control
  - Single event
- 80% of failed satellite had deployment mechanism
  - Complicated design, increase of single-point-of-failure

Application of COTS parts and technology in lean satellites (2014~)

- Many satellites used PIC16F877 or PIC16F877A as a microprocessor strong against radiation
  - Good flight record
  - Watches the satellite system constantly and does power cycling when anomaly occurs.

Characteristics of lean satellite program (IAA study)

- Positive use of COTS parts and technology
- Single points of failure are allowed
- Development and operation by a small team
- Care is taken so that a failure of single satellite does not jeopardize the satellite program
- Mission downtime is allowed
- Short mission duration
- Waste minimization in the satellite program
- Explosive and/or toxic materials are avoided
- Simple satellite system
- Minimum parts control

There may not be many satellites that have all

IAA Study on Definition and Requirements of Small Satellites Seeking Low-Cost and Fast-Delivery

Time to deliver a satellite	University satellite	Non-university satellite
More than 3 years	8	4
2 〜 3 years	8	2
1 〜 2 years	6	3
6 month 〜 1 year	2	2
Less than 6 month	0	0

Many university satellites spend 3 years or longer

Not fast-delivery

Slow-delivery of university satellites

- Less motivation for fast-delivery because labor cost is not an issue
- Students change over the time
  - Know-hows may not be passed down
  - Basis and background of various requirements may be forgotten
  - The basic principle of requirement management may be jeopardized
- Schedule delay due to communication with external entities, e.g. launch provider, government, etc..
  - Frequency coordination
  - Document exchange with the launcher
  - Cannot be controlled by students' efforts
- Technical delay
  - Students absorb by working night or weekend

Best practice to improve lean satellite reliability (2015~)

- Studied four Japanese university satellite projects
- Categorize university lean satellite projects into two types,
  - Distributed
  - Centralized

	Distributed project
Characteristics	• Satellite projects mainly by students • Made of 10 ~ 30 students • Decision making by students
Advantage	• Low cost • Educational effects
Disadvantage	• Not good efficiency • Task imbalance among members • Communication among members
Necessary items	• Training of new members • Frequent guidance by faulty and staffs • Documentations for information management

	Centralized project
Characteristics	• A few staffs (faculty and/or research staffs) are responsible for the satellite development and use their own hands • Staffs work on critical and/or technically difficult parts • Students participate from less-difficult parts • Decision making by staffs • The ideal number of members is approximately five
Advantage	• Easy information management • Minimize documentation • Prompt decision making • Easy to understand overall status
Disadvantage	• Continuity • For bigger satellites, outsourcing becomes necessary leading to more cost and black-box.
Necessary items	• High technical skills and satellite development experience of staff

Final words

- A proposal of university program style to improve the mission success rate
- Finish one generation in two years including operation
  - Utilize ISS release
  - CubeSat
- Launch every year
  - Replace a fraction of bus components step-by-step
  - Start the new project while the old project is still running
    - The experience and know-hows directly passed down to the new team.
- Distributed project by a small team (less than 10 people)
  - For a large number, increase the number of satellites and make it a constellation
- Integrate the program into university curriculum
- Satellite system and program will become very robust and reliable after 5 generations