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Economic analysis of a semi reusable launcher

2nd ESA CNES SPACE COST ENGINEERING CONFERENCE

17 of september 2021

Launch services prices drop sharply

Disruptive new entrant SpaceX offers low price on the satellite launch market.

- ✓ **Falcon 9 Semi Reusability Strategy implemented with the reuse of the 1ʳˢᵗ stage**

- ✓ **Recovery on ground or Drone Ship**

- ✓ **Refurbishing of 1ʳˢᵗ stage up to 10 flights for B1051**
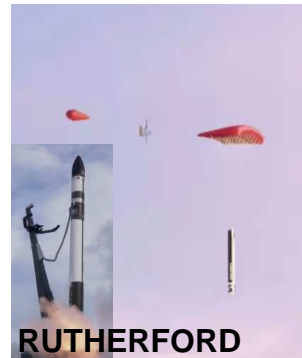
- ✓ **Extension of Semi Reusability to the half fairing**

2021 (Begin of September):
- **21 launches**
- **20 reused boosters**
- **19 boosters recovered successfully**
- **1 failures @ booster recovery**
  (Starlink L19)

ASOG (B1061.4)

Other tests or developments of SRLV (Europe not presented)

LAUNCHER ONE

ELECTRON

VULCAN

NEW-GLENN

RUTHERFORD

1 LAUNCH
2 CENTAUR RELEASES PAYLOAD
BOOSTER RELEASES ENGINE
3 HYPERSONIC RE-ENTRY WITH ADVANCED INFLATABLE SHIELD
4 PARAFOIL RECOVERY WITH MID-AIR CAPTURE
5 RE-CERTIFY
6 RE-ATTACH

BE-4

CZ-6X

JD-1

HYPERBOLA-2

NEWLINE-1

CZ-8

垂直起降重复使用运载器示意

STARSHIP

SRLV Cycle

Launch Véhicle	Production	Refurbishment	Launch	Orbit Weight	Recovery

REUSE

Expendable

Upper Part Expendable

1^{rst} Stage Expendablee

High Energy (GEO Escape)

1^{rst} stage Recovered

Upper Part Expendable

Low Energy (LEO SSO)

Recovery on ground or drone ship of 1^{rst} Stage

Refurbishment feasible depending of :
- ✓ recovery success
- ✓ level of damage due to recovery
- ✓ level of wear of the hardware

- ✓ **What is the of cost of :**
  - ➤ **Recovery**
  - ➤ **Refurbishment**
  with respect to the cost of new product 1^{rst} Stage

➔ IS IT WORTH IT ?
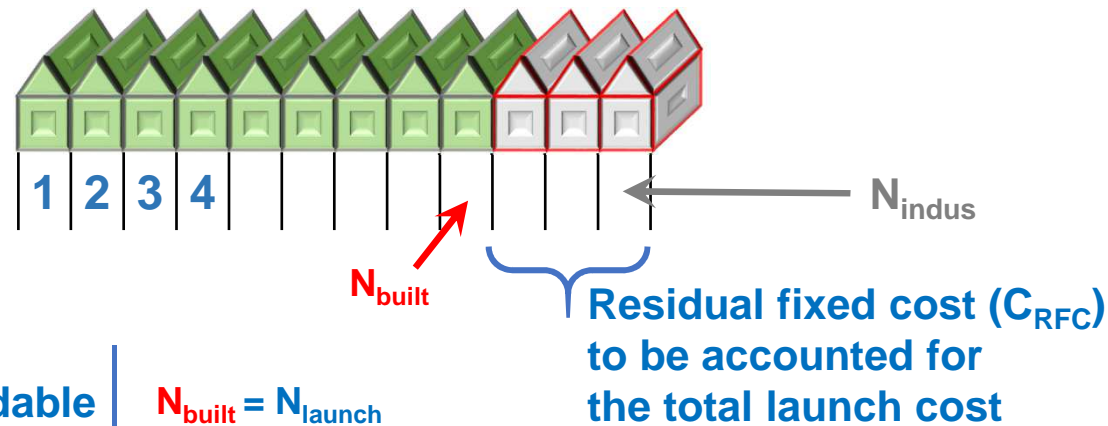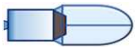
Modelling of Manufacturing, if not sourcing

Product of an element is defined with :
- **Standard Cost (C_{std}) = unitary Fixed cost + unitary Variable cost**
- **Production capacity of this element (N_{indus})**

Factory is sized for N_{indus} product.
The total fixed cost of this factory is N_{indus} x unitary Fixed cost

1 2 3 4

N_{indus}

N_{built}

Residual fixed cost (C_{RFC})
to be accounted for
the total launch cost

	Expendable	$N_{built} = N_{launch}$
	Reusable	$N_{built} < N_{launch}$

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Comparison of launch cost : ELV / SRLV Strategy

ELV Strategy:
For upper part and 1rst Stage
➢ $CT = N_{launch} \times C_{std} + C_{\#built\_RFC}$

SRLV Strategy:
For upper part (like ELV)
➢ $CT = N_{launch} \times C_{std} + C_{\#built\_upper\_stage\_RFC}$

For 1rst Stage, Introducing :
  U = the number of use
  K_{RRC} = The ratio of recovery and refurbishing cost / Standard cost
  τ_R = the recovery success ratio
➢ $CT = N_{built} \times C_{std} + N_{reuse} \times K_{RRC} \times C_{std} + C_{\#built\_1rst\_Stage\_RFC}$

SRLV Strategy is worth with respect to ELV Strategy if CT SRLV < CT ELV :

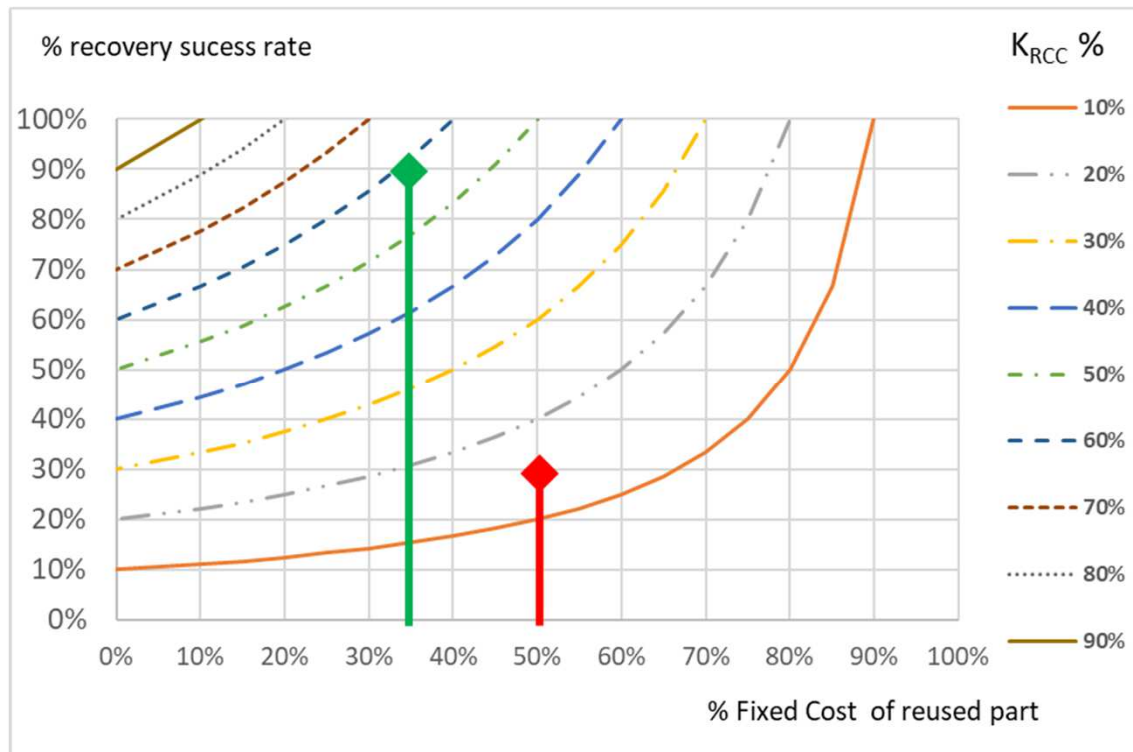➜ **SRLV STRATEGY IS WORTH IT IF :** $K_{RRC} < \tau_R (1 - C_{Fixed\_unitary} / C_{std})$

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Criteria for cost reduction of SRLV Strategy wrt to ELV one

$$K_{RRC} < \tau_R \, (1 - C_{Fixed\_unitary} / C_{std})$$

% recovery sucess rate

K_{RCC} %

— 10%
— · — 20%
— · — 30%
— — 40%
— · — 50%
— — 60%
— — — 70%
········· 80%
— 90%

% Fixed Cost of reused part

First case :
➤ **The fixed cost of reused part are high 50%**
➤ **The recovery is difficult 30%**

High constraint for K_{RRC} < 15%
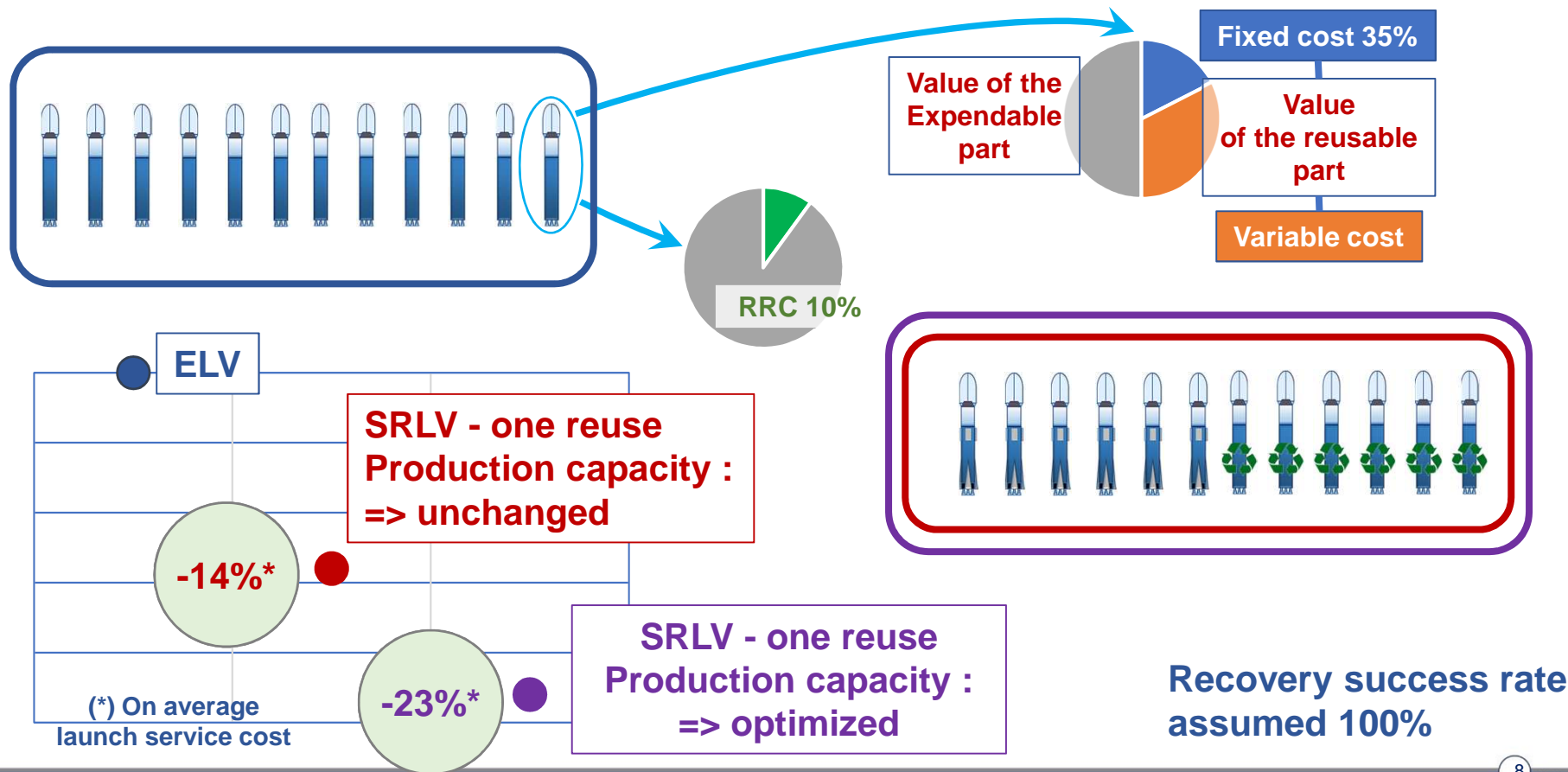
Second case :
➤ **The fixed cost of reused part are 35%**
➤ **The recovery is mastered 90%**

Low constraint on K_{RRC} < 60% => More cost reduction accessible

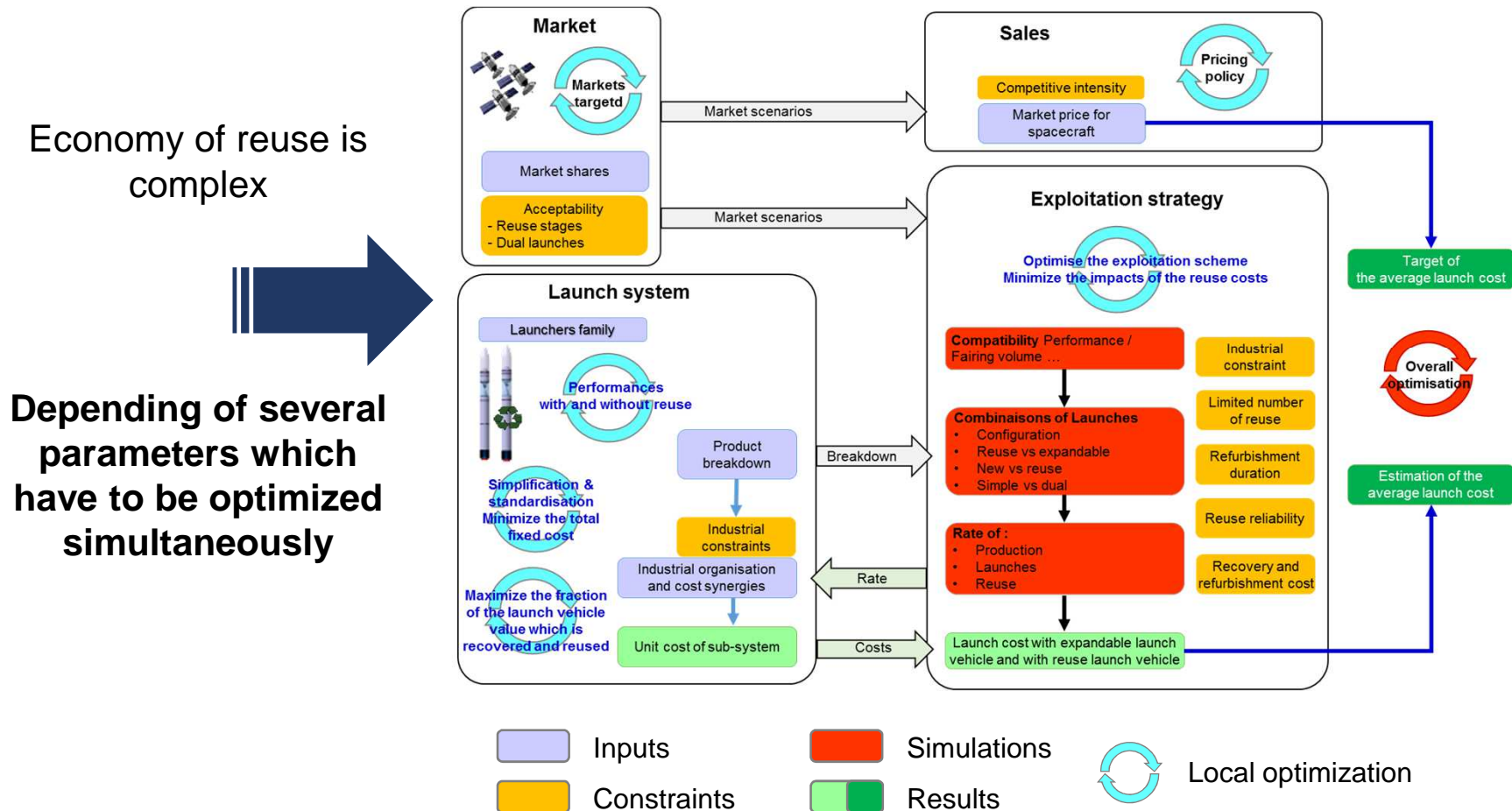**This criteria is, at first order, independent of the launch rate**

Example of cost reduction of SLRV vs ELV Strategy

Comparison of launch service recurring cost for 12 launches /year

Fixed cost 35%

Value of the Expendable part

Value of the reusable part

Variable cost

RRC 10%

ELV

SRLV - one reuse Production capacity : => unchanged

-14%*

-23%*

(*) On average launch service cost

SRLV - one reuse Production capacity : => optimized

Recovery success rate assumed 100%

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Sketch for economy for reuse evaluation

Economy of reuse is complex

Depending of several parameters which have to be optimized simultaneously

SRLV strategy is worth to help targeting low price market:

- ✓ **Criteria is met**

- ✓ **The proportion of cost value of reuse elements must be maximized**

- ✓ **The fixed cost must be minimized**

- ✓ **Mastering of recovery is necessary**

- ✓ **Reducing the recovery and refurbishment cost**

- ✓ **The simplification of the design of the launcher must be taken into account from the beginning in order to decrease the initial cost**
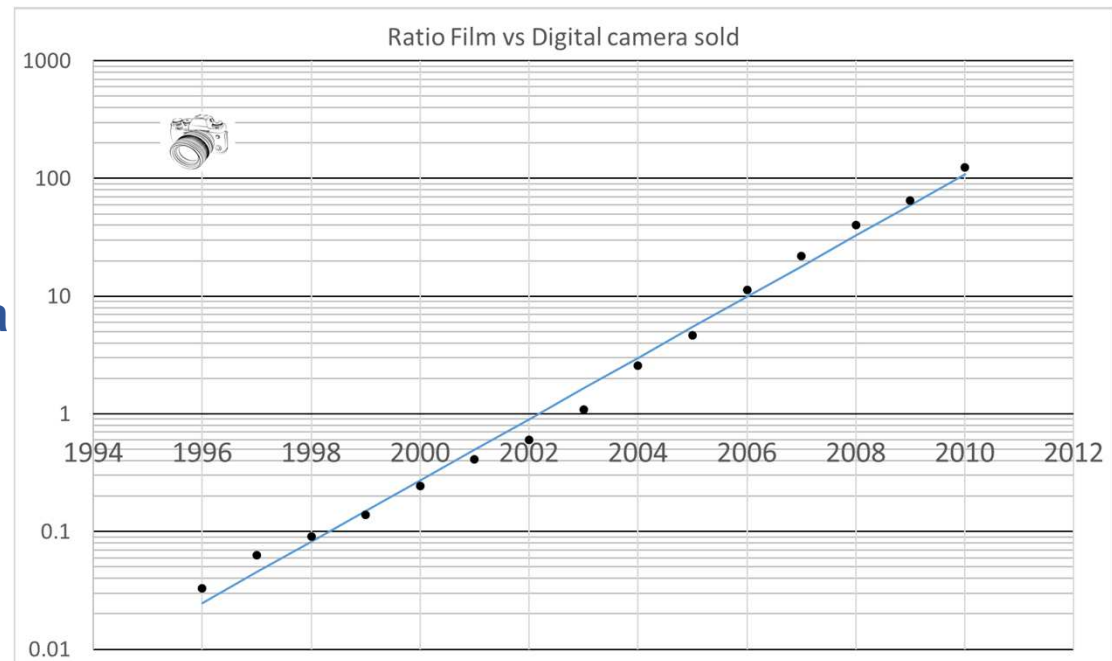
Substitution Concept

What is Technological Substitution?

Technological substitution is the customer's preference of one product over the other due to the technological advancement available in the product.

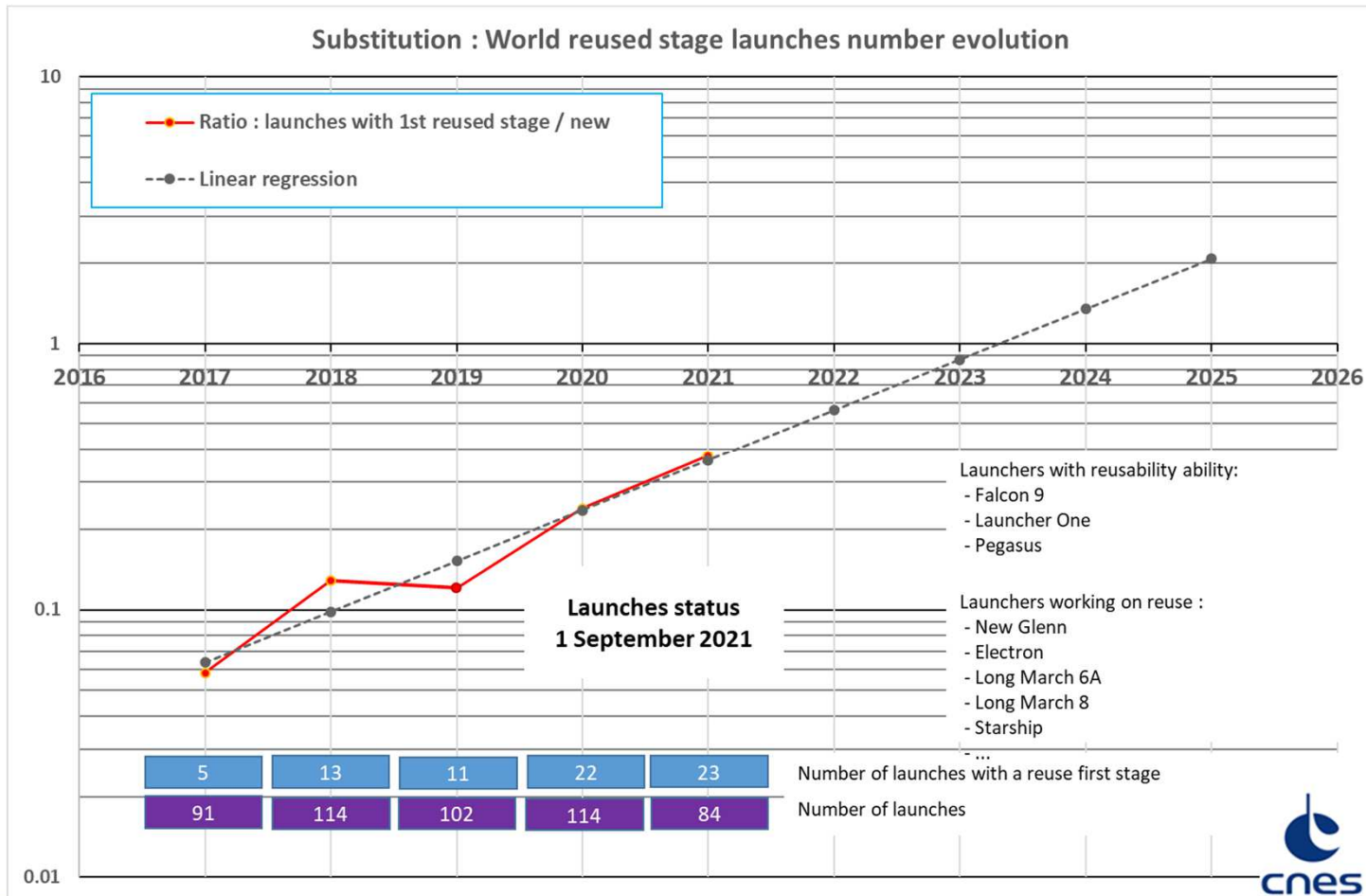**Forecasting the temporal evolution of old VS new product sold is achievable.**

✓ **Example: Film camera was substituted by Digital camera**

Ratio Film vs Digital camera sold

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Substitution success criteria:

✓ **Substitution cost : No over cost for the client due to reusability**

✓ **Product cost : reusability decreases launch costs**

✓ **Quality: Falcon similar to A5**

✓ **Functionalities: reused stage and new stage are fully interchangeable**

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Substitution concept applied to Reusable Launcher

Substitution : World reused stage launches number evolution

Launches status
1 September 2021

Launchers with reusability ability:
- Falcon 9
- Launcher One
- Pegasus

Launchers working on reuse :
- New Glenn
- Electron
- Long March 6A
- Long March 8
- Starship
- ...

| 5 | 13 | 11 | 22 | 23 | Number of launches with a reuse first stage |
| 91 | 114 | 102 | 114 | 84 | Number of launches |

Thank you for your attention !

Any questions?

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