Beyond Software

lowRISC's Framework for Open Source Silicon Design

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CEO and co-founder, lowRISC CIC

"Practical Technologies: Open Technology Frameworks"
SynBio Forum: Tools for Engineering Biology Series
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A brief introduction to lowRISC CIC

lowRISC is a **not for profit UK company**

Our **goal** is to help make **open source silicon design** a **reality**

We are uniquely positioned:

- Spun-out from the University of Cambridge Computer Lab
- Chaired by Prof Sir Andy Hopper; an early example of his 'Newlabs' model
- Attracted sustainable funding from major industry players (e.g., Google), so far *without* government assistance
- Unconflicted not-for-profit (C.I.C.)
- Breadth of industry partnerships and academic connections
- Full stack engineering capabilities (hardware, software, tooling)

Pedigree of hitting milestones in complex, commercially-funded projects including:

opentitan LLVM Ibex

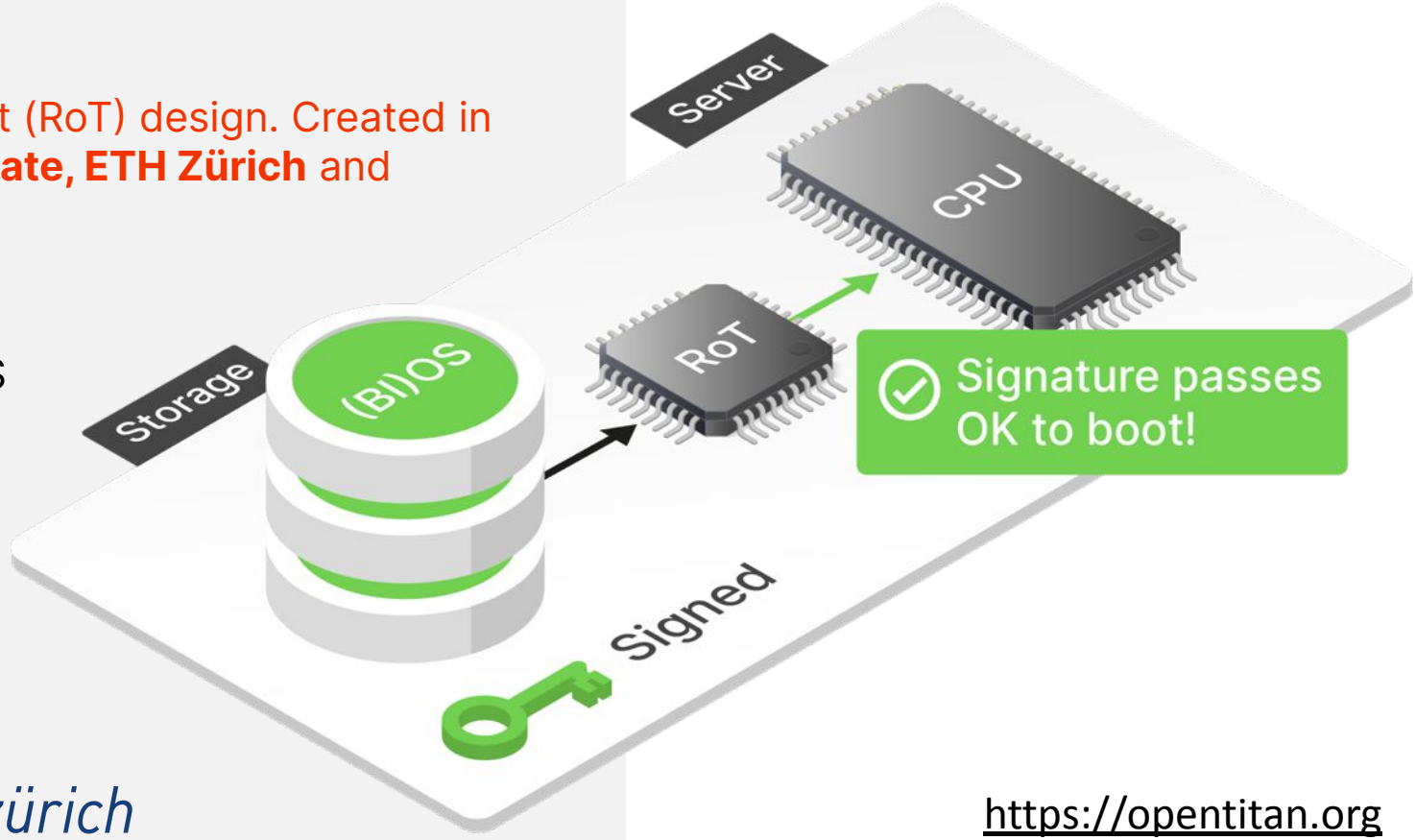
Our flagship project:

opentitan

The world's first open source silicon root of trust (RoT) design. Created in partnership with **Google, Western Digital, Seagate, ETH Zürich** and others

The root of trust ensures:

- First instruction integrity, independent of O/S
- 'TPM' functionality (stores network secrets etc) once booted
- Tamper-evident h/w audit trail
- Cryptographic attestation



https://opentitan.org
https://github.com/lowrisc

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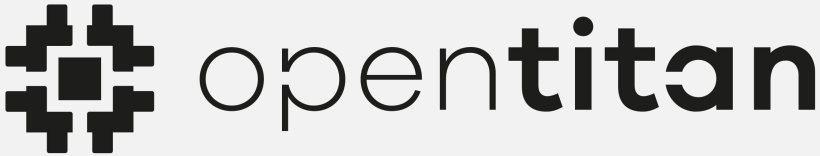

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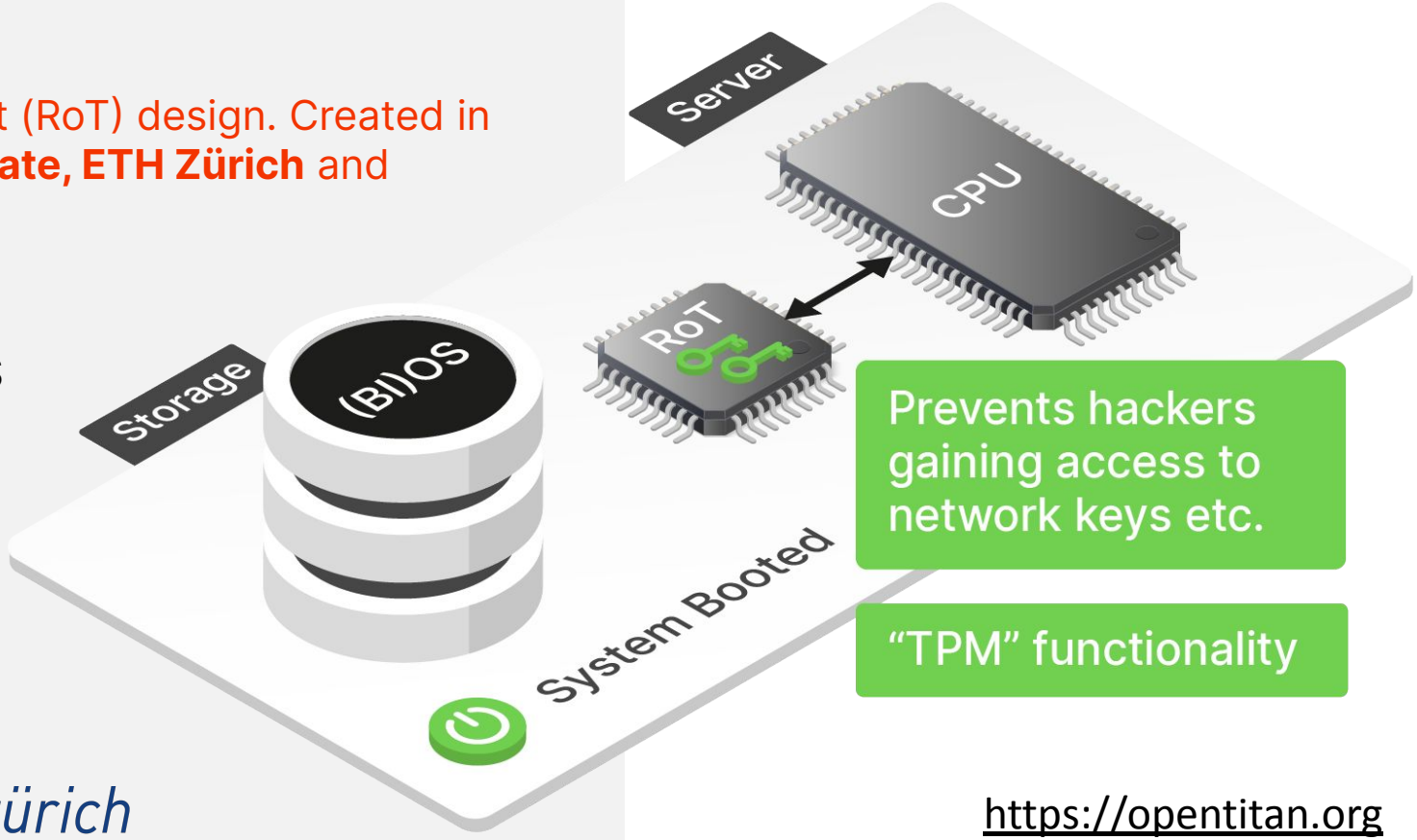

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The core problem

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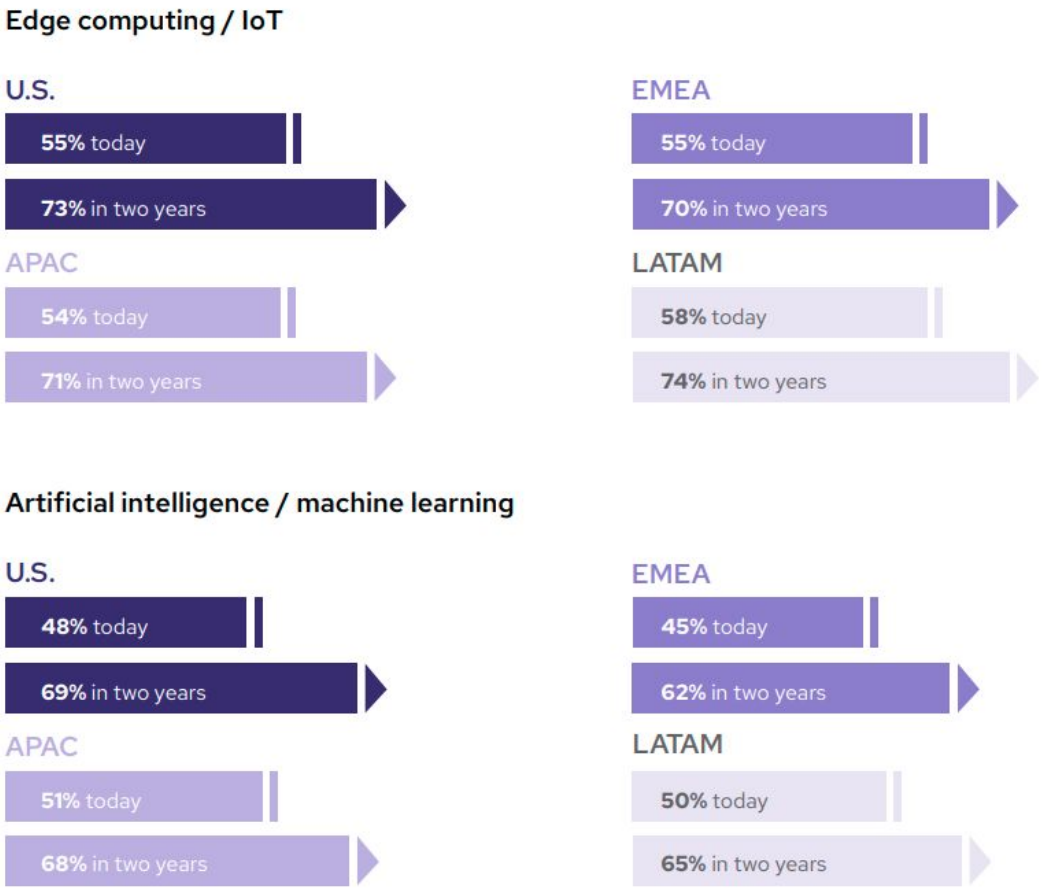
Is the success of open source software (!)

Undoubtedly, open source has proven a transformative approach for software:

- Vast majority (>95%) of mainstream smartphones use an open-source-derived kernel (Android, iOS)
- 70% of global mobile subscribers use networks built using ONAP
- 100% of supercomputers use Linux
- 50% of global car shipments supported by OEMs using Automotive Grade Linux
- >1 billion web security certificates issued by Let's Encrypt (now world's largest certificate authority)
- Many up-stack libraries, apps, and tooling (GCC, LLVM etc) are open-source
- Replacing patents as the dominant social contract around IP

Source: Linux Foundation, August 2021

Use of open source software in emerging technologies:



Source: Red Hat 2021 State of Open Source Report

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Because: hardware design is *different*

Most real-world engineering endeavours are **more like silicon design than software…** there's **no direct read across from** best practices in **open source software** to other domains:

	Software (typical project)	**Silicon design (typical project)**
Available skilled engineers	Many	Few
Tooling	Largely free	Mostly proprietary & expensive
Design turnaround	Months	Years
Bug fixes after deployment	Straightforward	Often impossible
End product	Virtual	Physical (mask costs, distribution etc.)
100% open IP for end product	Often possible	Currently impossible

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lowRISC's approach

lowRISC's core mission — from its foundation in 2014 — has been to *address* these key differences, taking an approach to open source silicon design that is:

- **Credible**
- **Sustainable**, and
- **Impactful**

It has been a long journey since then, but now, as **OpenTitan** — our flagship project — nears its first engineering sample tapout, having become:

- the **world's largest** collaborative **open source silicon project**, and
- the **world's first** open source silicon **root of trust** design

we thought it would be a good time to disseminate some of the concrete implementation insights gained along the way

So, in this short presentation, we'll explore each of the **three themes** above, and share the **key secrets behind our success** thus far

Credible

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Why a non-profit org is needed

Existing ecosystem **players** have **limited ability to act** as the trusted steward of open source silicon design projects, because:

- **Conflict of interest** limits the cooperation and sharing **for-profits** will engage in
- **Universities** cannot realistically create high-quality, fully documented, supported IP — it's **not their core mission**
- **Simple repos of donated IP** suffer from '**bit rot**'
- **Specifications groups** are often divorced from **real-world** use cases
- **Community-led** approaches usually start from the open source software paradigm, then fail due to the **differences** highlighted earlier (need for up-front, multi-year funding etc)

lowRISC was founded on the assumption that a **different approach** was needed

lowRISC: a credible approach to collaborative silicon design

lowRISC CIC:

- is an **engineering** company, with '**full stack**' competence (we have DD, DV, firmware and tool engineers, PM resource), *not* just a coordinator
- is a **non-profit** (CIC), **unconflicted**, no shareholders so cannot be bought
- is **small**, domain focused, <50 people
- maintains close contact with **universities**
- acts as the **trusted steward** of one or more real-world projects, maintaining neutrality between potentially competing for-profits (such as Western Digital / Seagate), and
- **releases** the **foundational IP** created during the project under a permissive open-source licence, and commits to **maintain** it

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Sustainable

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Multi-year funding

A non-profit org still needs **funding**. From where to get it?

- **Governments** are typically **reluctant** to invest in new paradigms and outside of their 'innovation comfort zone' (unis, JVs etc)
- Meaning that **commercial funding** is required (and, given lengthy timelines, this needs to be a multi-year commitment)

But **why** would any for-profit want to do this? What's in it for them?

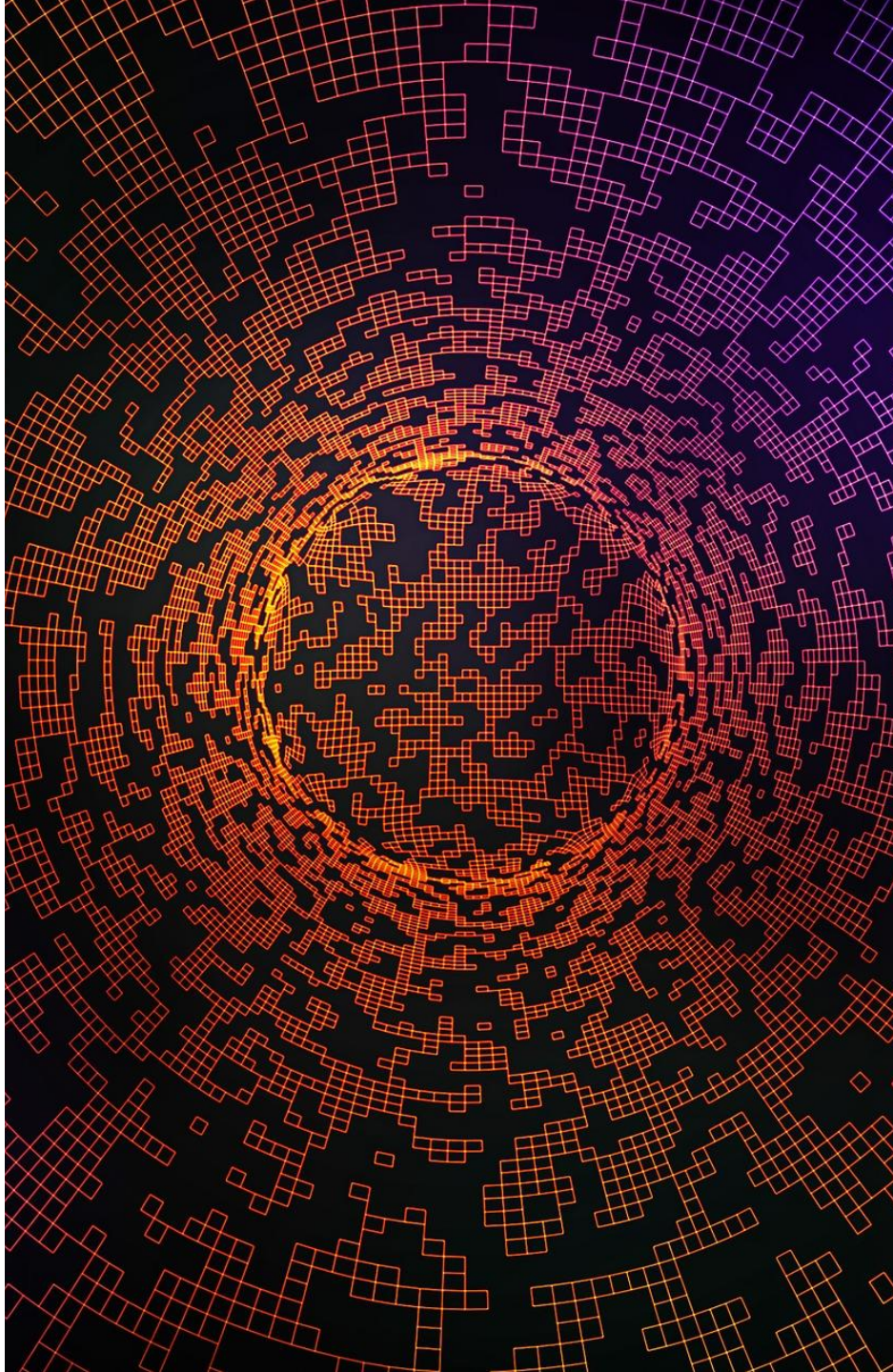
Well, **lowRISC CIC** *has* been funded **exclusively by the private sector** since inception; and we have found the primary motivator to be:

- **Safely upstreaming** their **downside differentiators**

With secondary motivators being:

- **Improved security** through scrutiny (Kerckhoffs' principle etc)
- **Optics** :)
- Helping secure a **second source of supply** (rapidly becoming primary)

Let's dive into a few of these points in more detail



Primary funding driver…

…safely upstreaming their **downside differentiators**?? Let's unpack this:

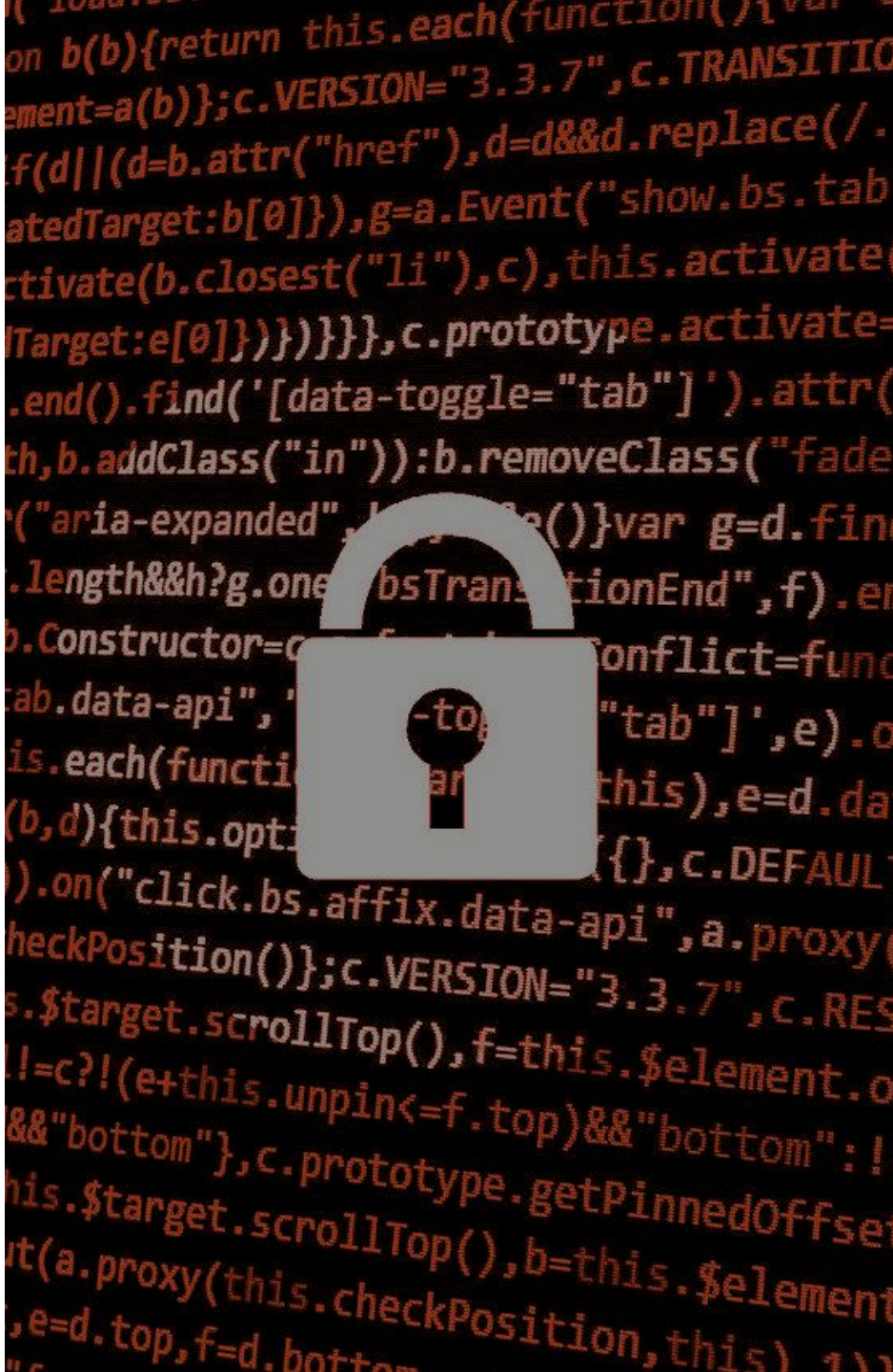
- A **downside differentiator** is something that isn't (particularly) a **USP** of your business, unless it **goes wrong**
  - For example, airworthiness for a plane, security for a server

If the downside is bad enough, companies end up building components critical to these properties in-house, thus tying up valuable engineering resource (opportunity cost); of course, they'd *like* to buy a CotS replacement, but often feel they can't do so:

- **Safely**, as they're (usually) unable to determine quality etc

An **open source** approach potentially **solves** this, allowing them to publish a (clean room designed) version of their own design for **maintenance by others** (in exchange for that IP being usable by everyone):

- This **upstreaming** is a unique feature of open source collaboration
  - A **reversal** of the usual roles of IP producer and consumer
  - Key **metric**: value to others of IP < in-house maintenance cost



Upstreaming

For further details please see my Royal Society talk, "Zero and Everyone"

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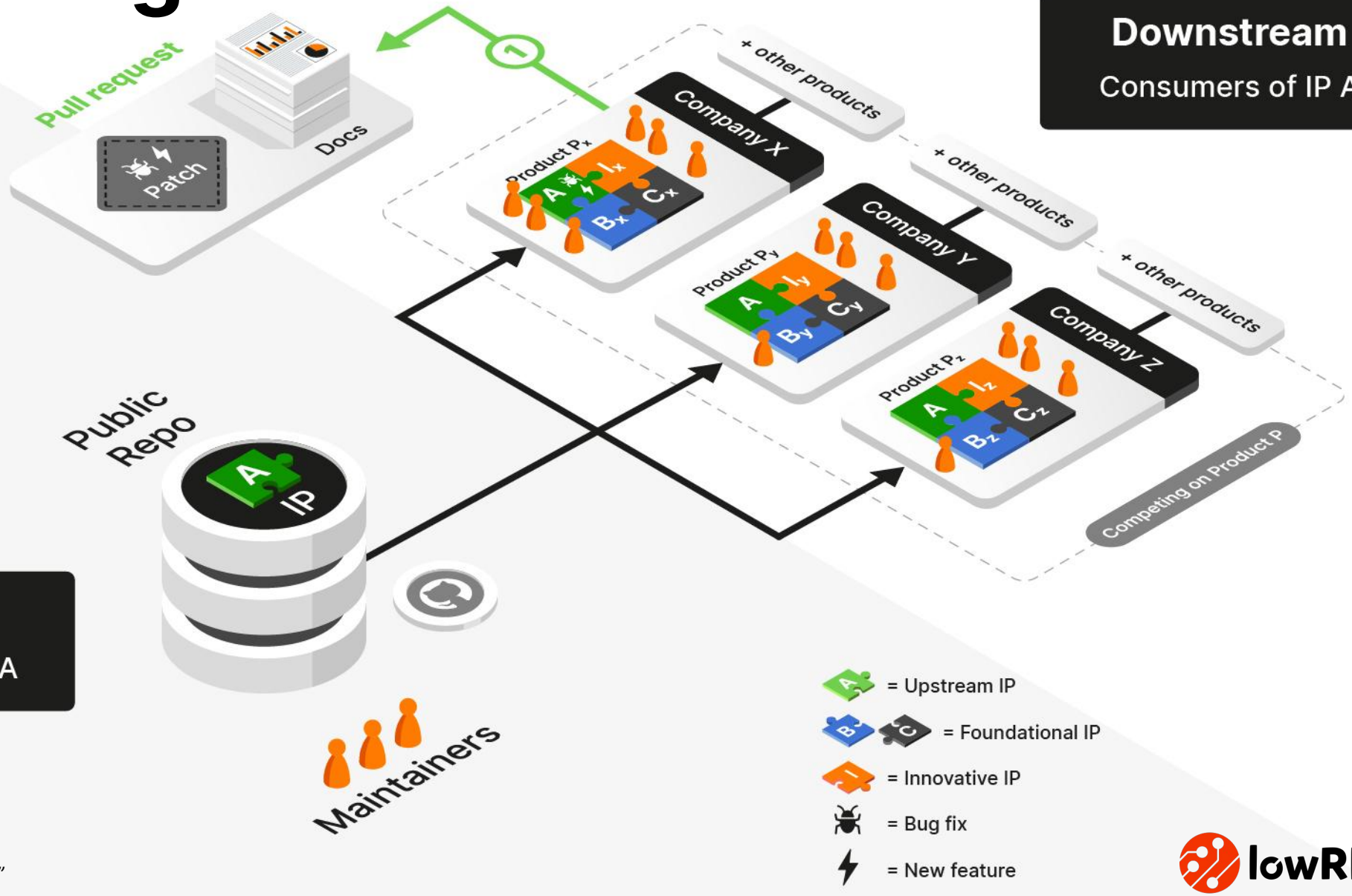

Downstream
Consumers of IP A

Upstream
Maintainers of IP A

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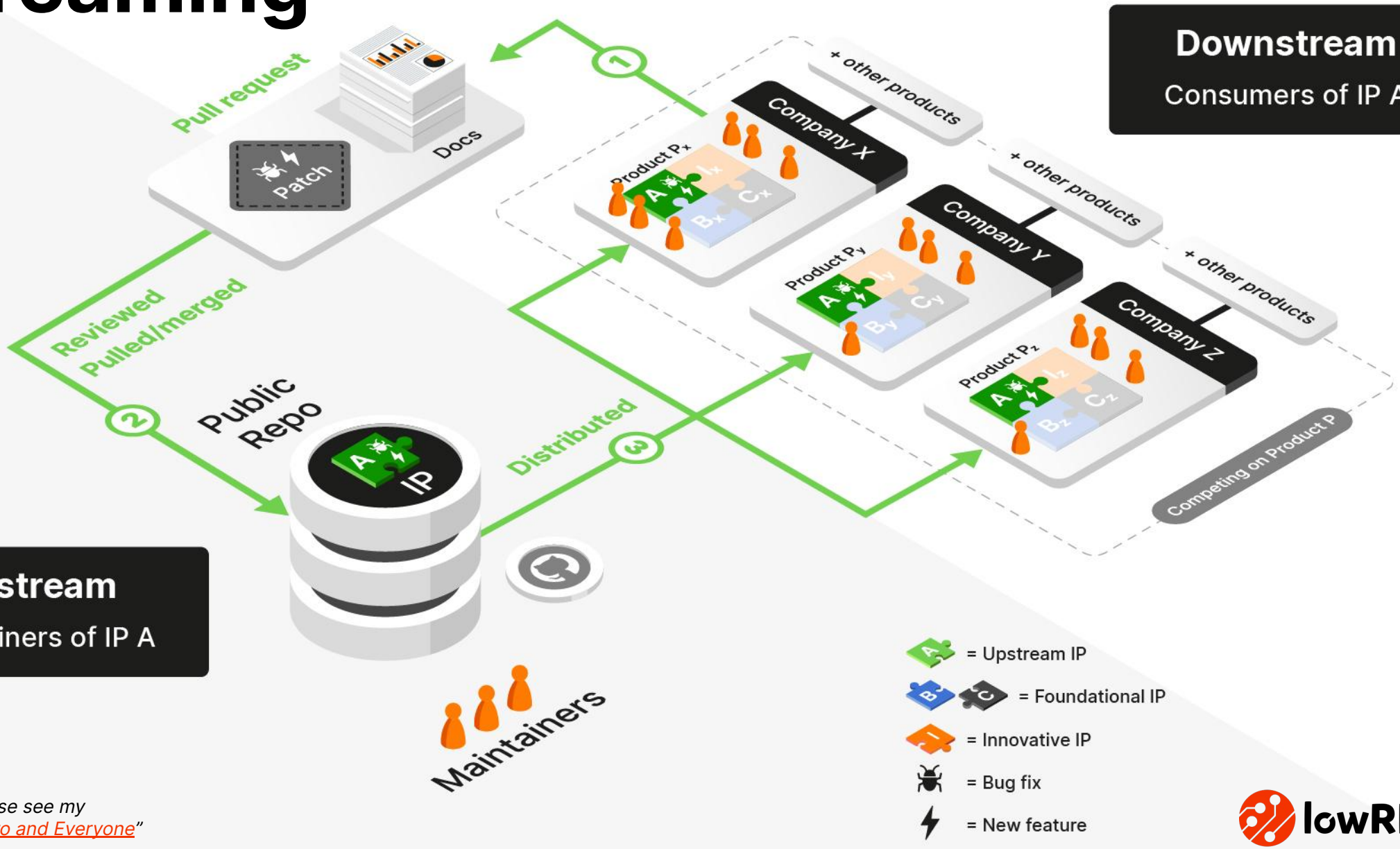

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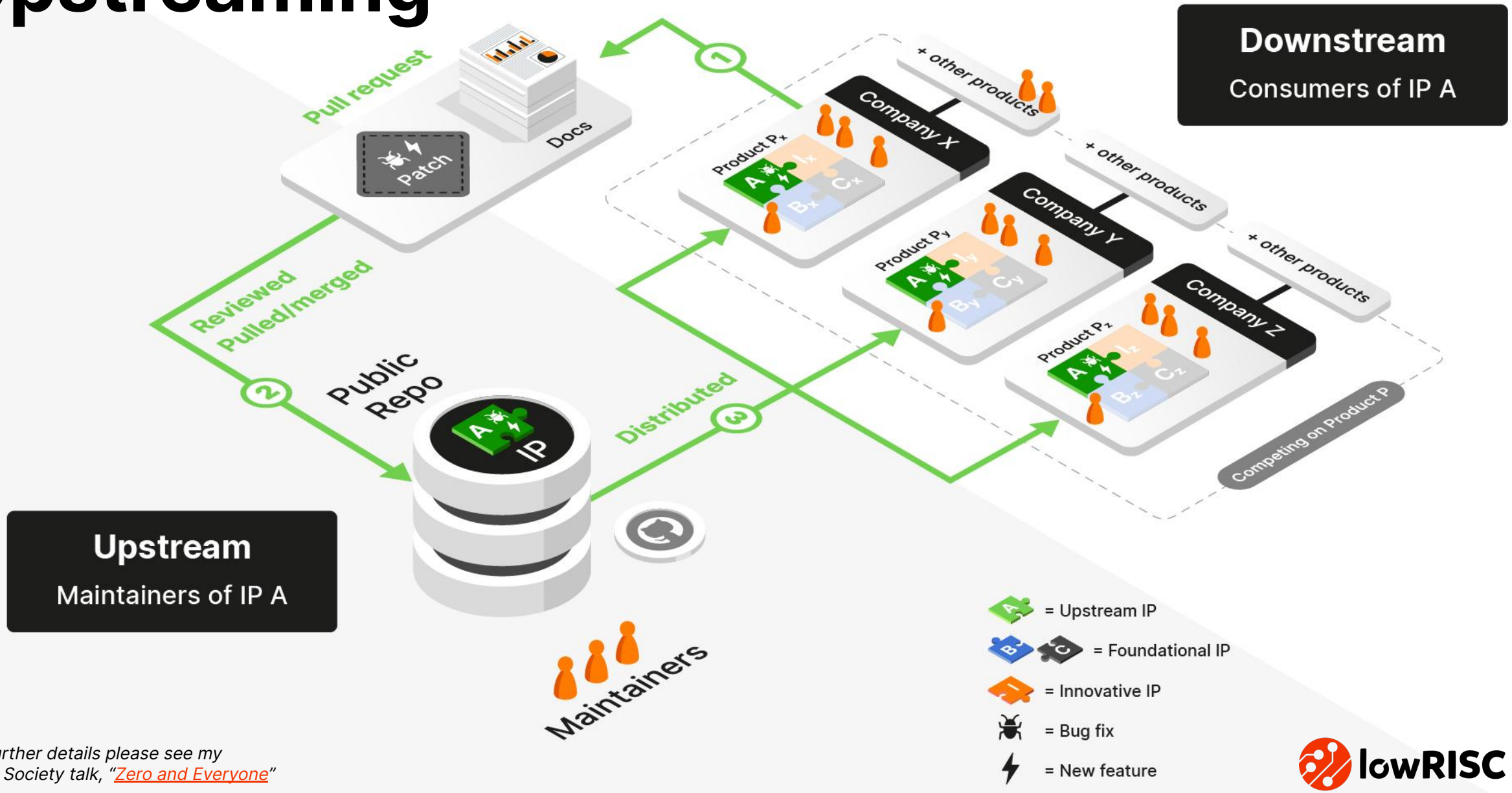

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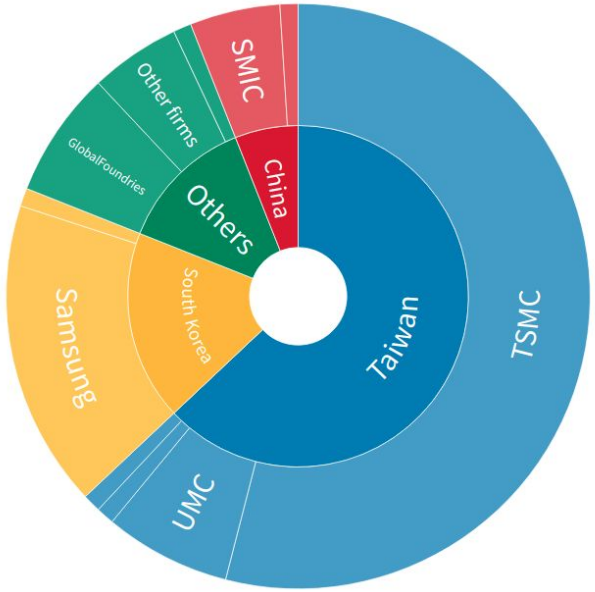
Second sourcing

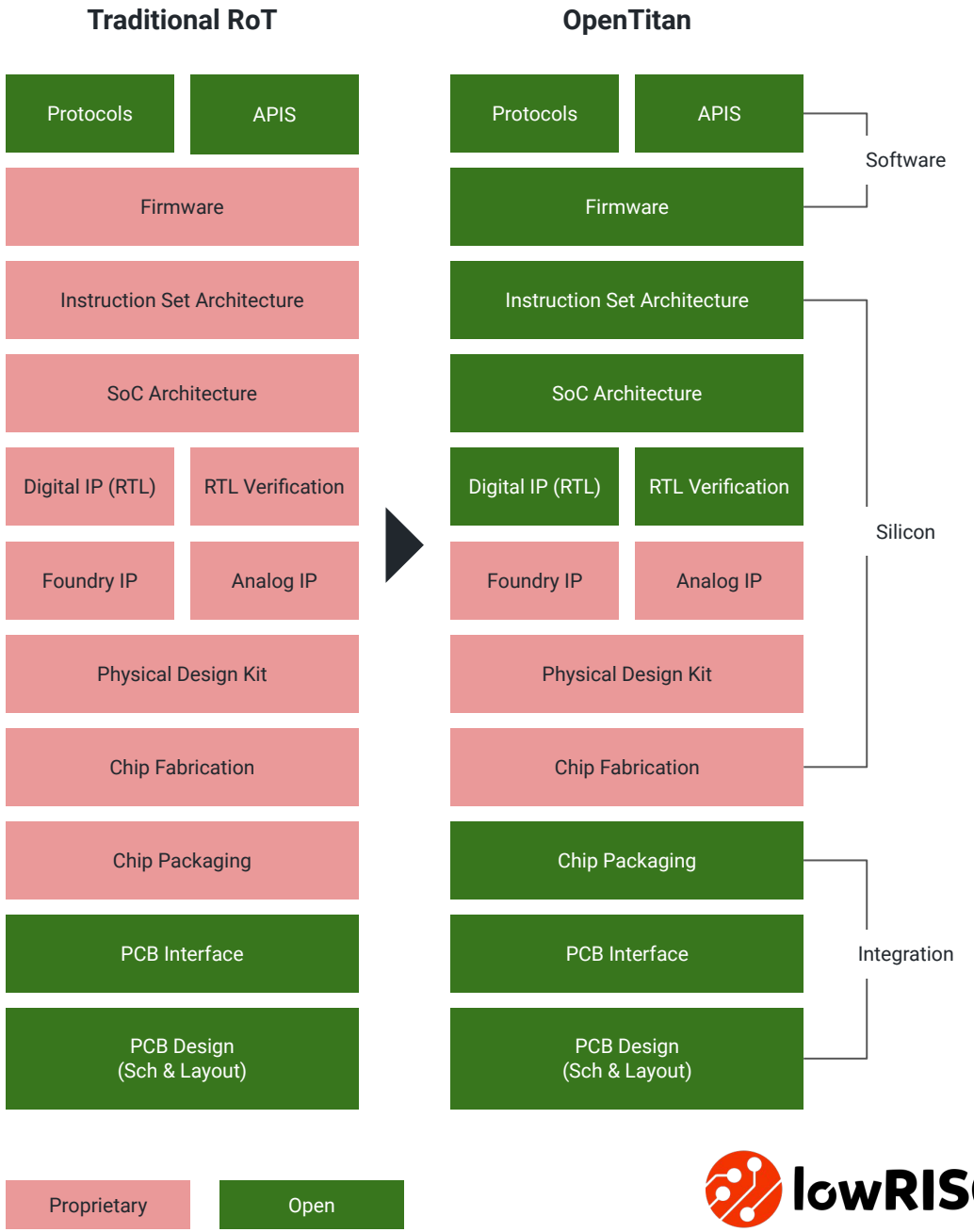
Due to the current silicon squeeze and geopolitical concerns, manufacturers are looking for **diversity of supply**

- With an **OpenTitan**-based design, the **tied elements** (aka 'mystery meat') in the design stack are **significantly reduced**, assisting second sourcing

Semiconductor contract manufacturers by market share
Total foundry revenue stood at $85.13 billion in 2020



Source: Trend Force, March 2021; CNBC



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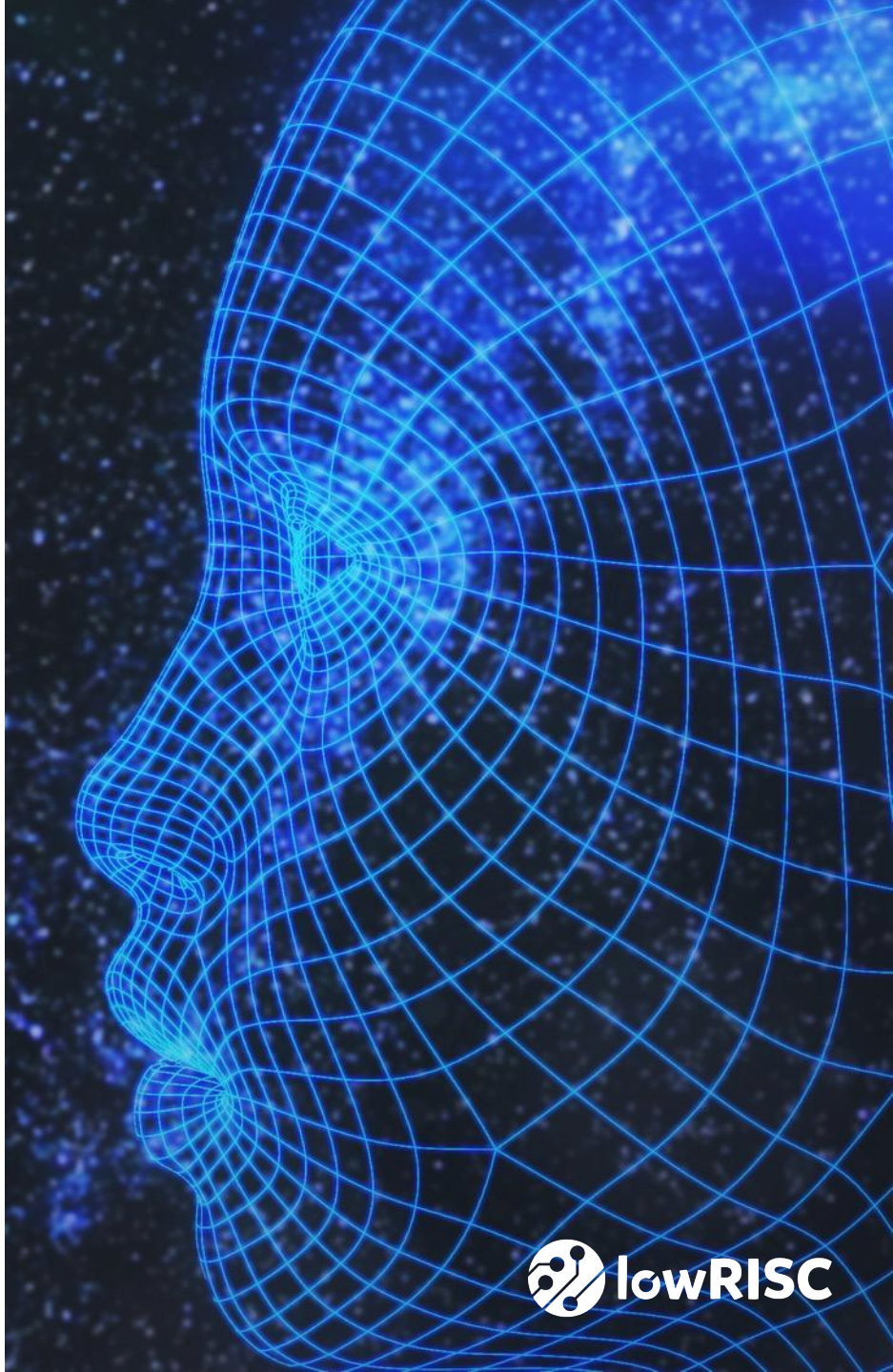
Besides funding: staffing

Another key driver for sustainability is **staffing**

How does a **non-profit** hire, motivate and retain its staff,
in an increasingly tight job market?

There's no simple answer, but some things we have found useful are:

- Using an annual **salary survey** to tie base remuneration to industry norms
- Actively supporting '**braided careers**' with academia
- Having realistic support for **flexible working arrangements** (3d/2d split for experienced staff, etc)
- Supporting '**10% time**', to allow staff to contribute more broadly to the open source ecosystem
- Requiring project **partner orgs** to **contribute FTEs**, not just funding
- Being **flexible** about **geographic reach** (tier 2 visa sponsorship is no longer a luxury, particularly post-Brexit)



Impactful

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Moving the needle

So, our approach can help for-profits get what *they* want,
but what about *our* CIC mission?

The key thing here is dealing (in multiple senses) with **boundaries**:

- Build IP at **product scope**, so **components** can be reused
- Set (and enforce) **interfaces between devs**: for contributions (coding standards), protocols for review, RACIs for design and signoff
- Ditto for the **interface between orgs**: a proper governance structure is vital (PD, SC, TC, standing meetings, annual roadmap etc)
- Explicitly embrace the **project / product split**: realities include embargoed repos, ‘shadow’ components, cert-sensitive flows etc
- Ensure **licensing terms** are clear (non-viral for contributors, certainty of reusability for wider ecosystem — we chose Apache 2.0 with CLA)
- Ensure key **project management tools and flows** (design decision register, top opens, resource maps etc) are agreed and shared

Upstreaming

Recap of the traditional approach

Downstream
Consumers of IP A

Upstream
Maintainers of IP A

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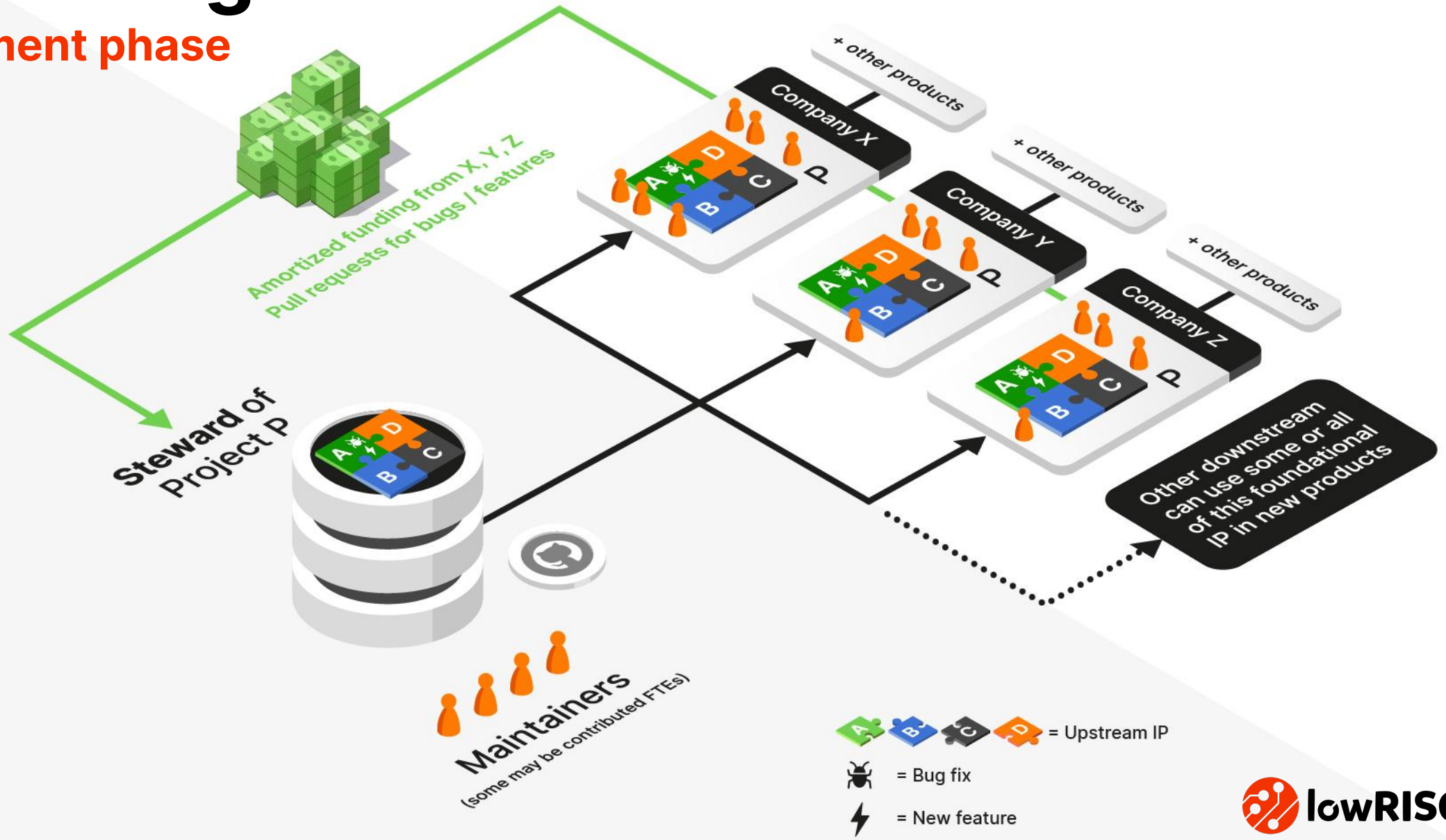
Stewarding

Development phase



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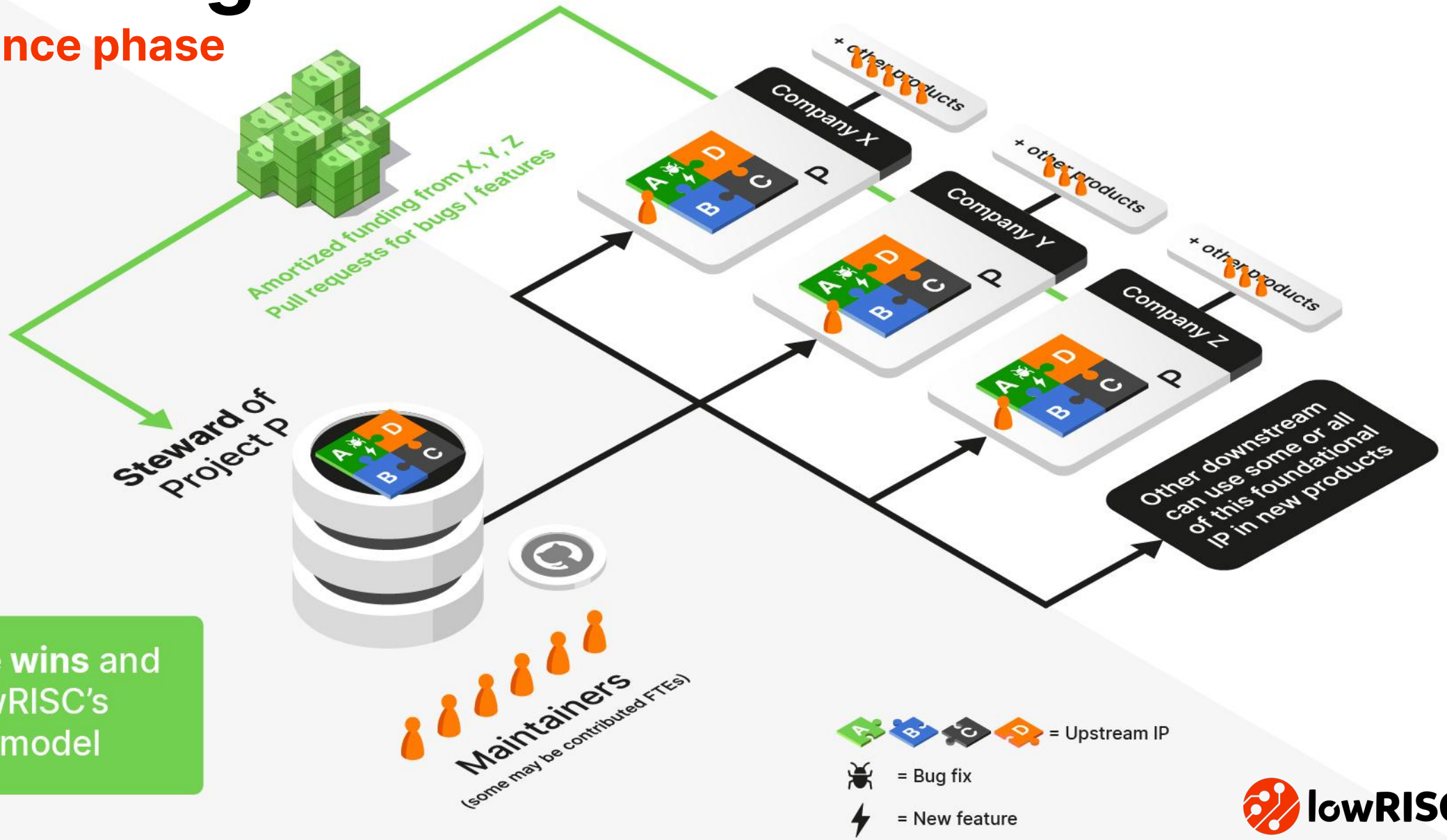
Stewarding

Maintenance phase



Everyone wins and this is lowRISC's business model

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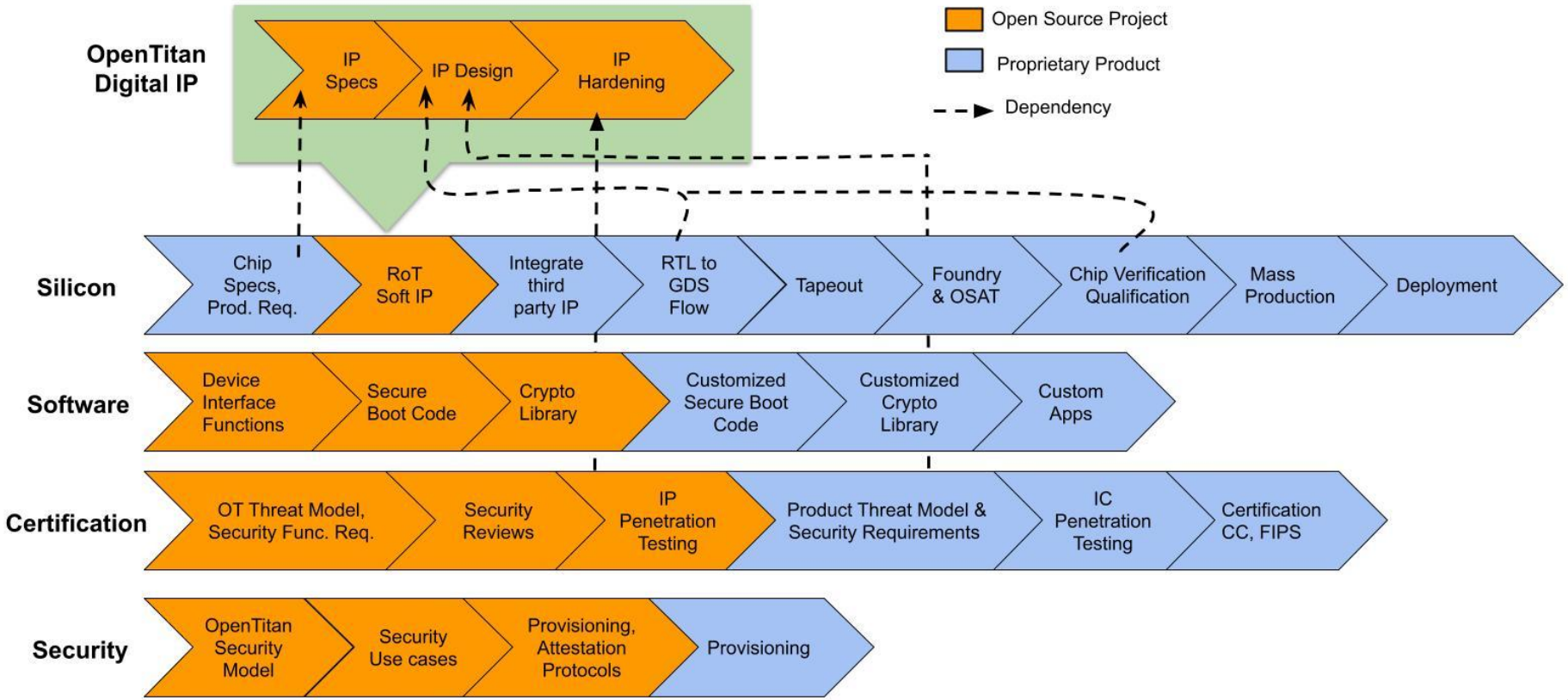
The project / product boundary

Real-world silicon products **require** use of **closed source** / **restrictively licensed IP**. Moreover, there is **bidirectional traffic** needed between the open and closed source domain. This is *quite different from what generally happens in software*, and requires explicit handling (legals, governance, firewalls):



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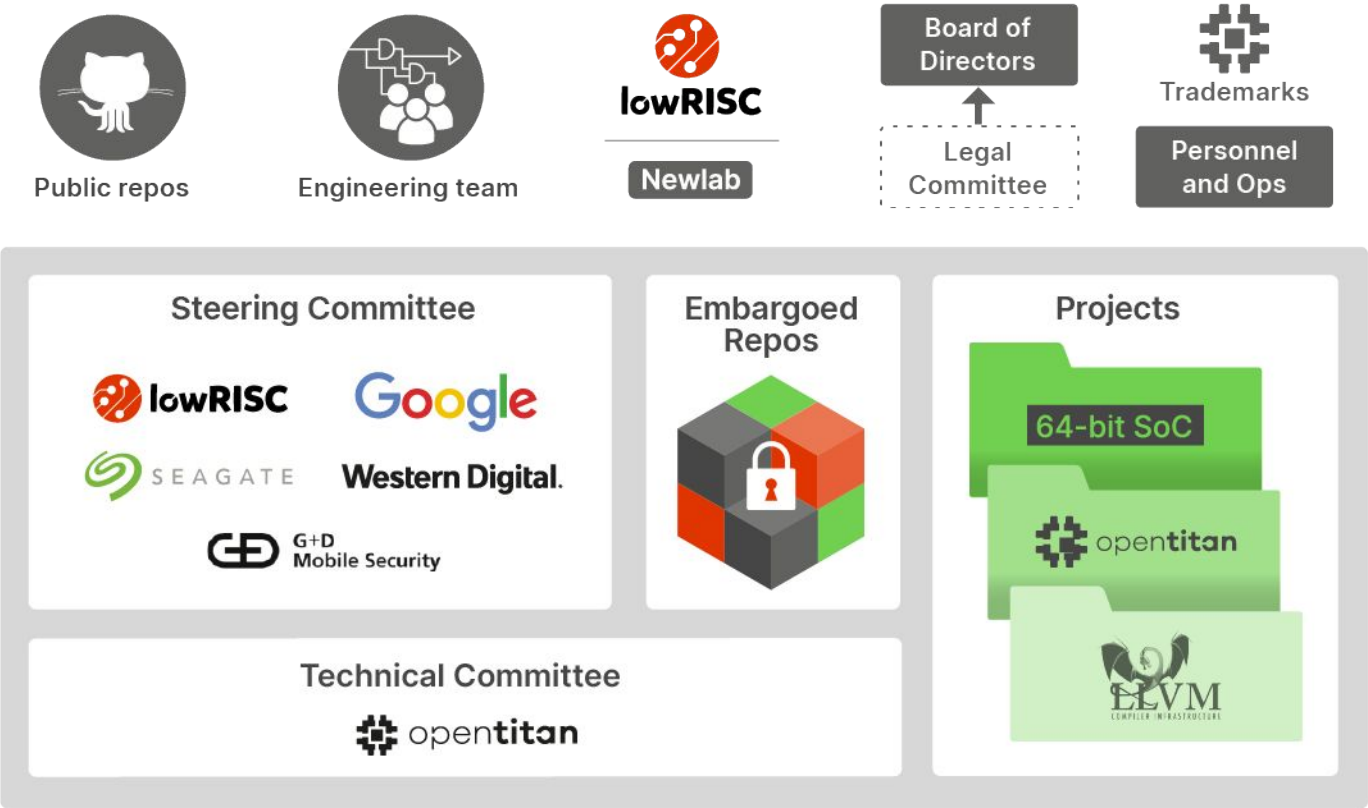
lowRISC's governance structure

is integrated with our business model, enabling us to:

- be a participant-funded, unconflicted **upstream** for real-world project(s)
- **publish and maintain** the resulting **foundational IP** artefacts (= logical infrastructure / digital commons)
- **bring together** potentially competing for-profits, universities, and the broader open-source community; and
- **steward** (as well as participate in) **full project** development, from inception



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Summary: lowRISC's business model

- **Credible**
- **Sustainable**
- **Impactful**

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Thank you!

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Contact information

For further information, please contact:

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https://opentitan.org

Supporting slides

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lowRISC's Board

Prof Sir Andy Hopper CBE FIET FREng FRS Independent Chair

Treasurer and Vice-President of the Royal Society, Professor of Computer Technology, former Head of the University of Cambridge Department of Computer Science and Technology. Research Director of Acorn at the time the ARM processor was created.

Co-founders:

Dr Gavin Ferris CEO

Uni. of Cam alumnus, co-founder of RadioScape, former software lead at DreamWorks SKG and CIO of Aspect Capital (a multi-billion $ computational hedge fund).

Alex Bradbury CTO

Uni. of Cam alumnus, former Linux lead developer for Raspberry Pi, code owner and primary author of RISC-V support in the LLVM compiler project.

Dr Rob Mullins Director

Co-founder of the Raspberry Pi Foundation, Reader in Computer Architecture at University of Cambridge, research focus is hardware accelerators for machine learning and many-core processors.

Prof Sir Andy Hopper

CBE FIET FREng FRS
Chair of lowRISC

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lowRISC's Board

Dominic Rizzo Director

OpenTitan project director at Google, previously Project Vault project director and tech lead on a successfully delivered Google FIPS Security Key project.

Dr Ron Minnich Director

Software Engineer at Google. A long time contributor to numerous open-source projects. He started the LinuxBIOS project in 1999, which was renamed to coreboot in 2008 and is now used in tens of millions of Chromebooks.

Dr Mark Hayter Observer

Sr Engineering Director in the Chrome OS Hardware team at Google. Prior to Google he was involved in systems architecture at several semiconductor companies, being VP of Systems Engineering at P.A. Semi, Inc. (acquired by Apple Inc.), Senior Manager of Hardware Systems Engineering at Broadcom Corporation and System Architect at SiByte, Inc. Earlier, he was at the Digital Equipment Corporation Systems Research Center.

Prof. Luca Benini Director

Holds the Chair of Digital Circuits and Systems at ETH Zurich and is Full Professor at the Universita di Bologna. He received a PhD from Stanford University. He has been visiting professor at Stanford University, IMEC, EPFL. Between 2009-2012 he served as Chief Architect in STmicroelectronics France.

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