



Towards New International Cryptographic Standards

Léo Perrin

► To cite this version:

Léo Perrin. Towards New International Cryptographic Standards. FIC 2020 - International Cybersecurity Forum, Jan 2020, Lille, France. hal-03136274

HAL Id: hal-03136274

<https://inria.hal.science/hal-03136274>

Submitted on 9 Feb 2021

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Towards New International Cryptographic Standards

Designing and Breaking Cryptography

Léo Perrin
Cosmiq TEAM
Inria, Paris, France

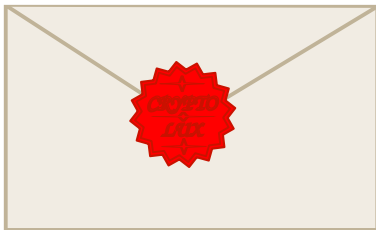
FIC 2020, Lille



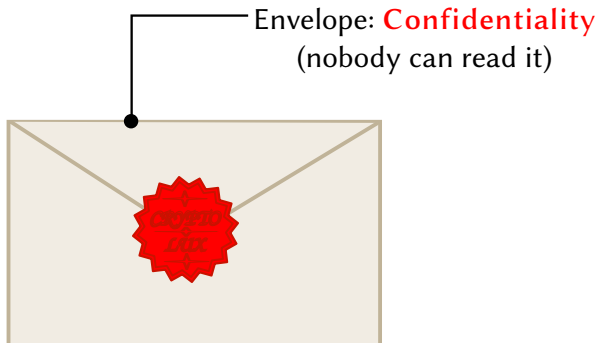
We (the **Cosmiq** team) are working on the foundations of cryptography.

- 1 What kind of algorithms do we study?
- 2 Why do we design new ones?
- 3 What kind of flaws do we find in other ones?

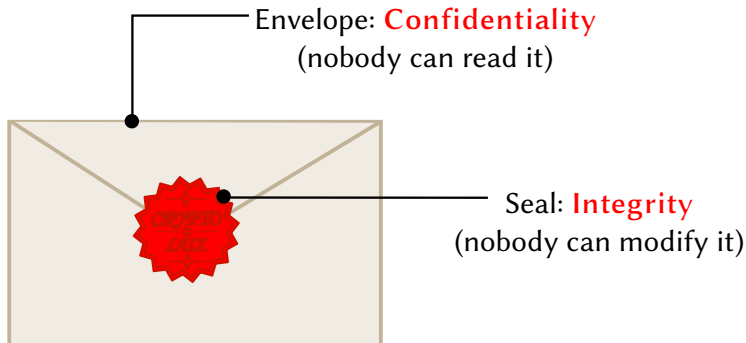
What is Cryptography?



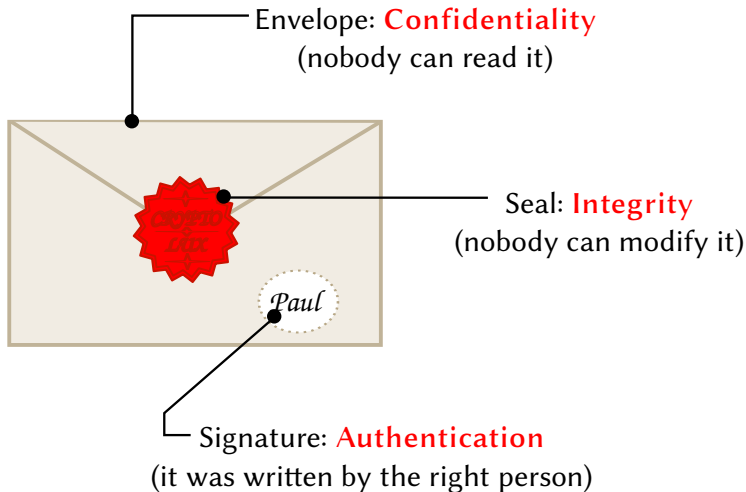
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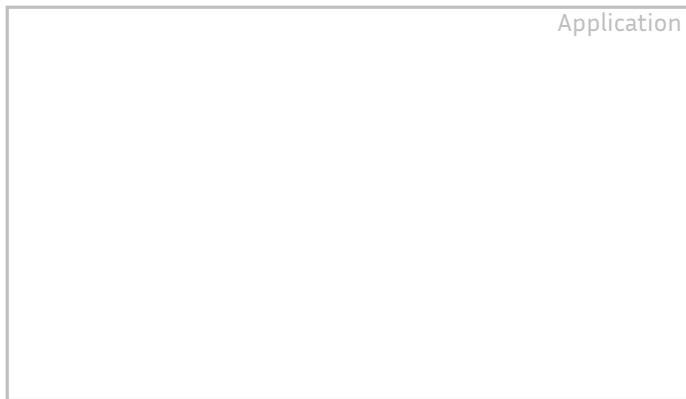
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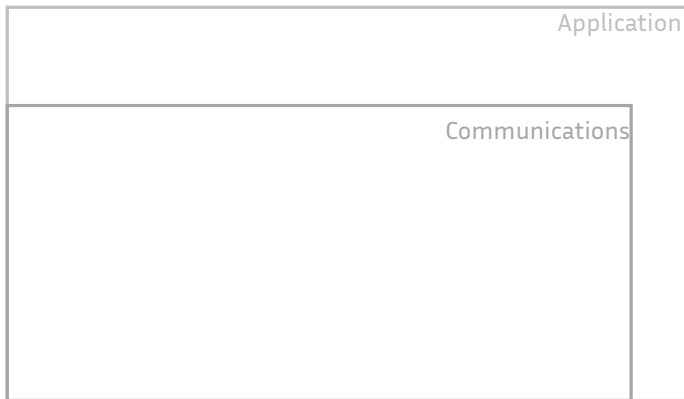
What is Cryptography?



How Is It Used?



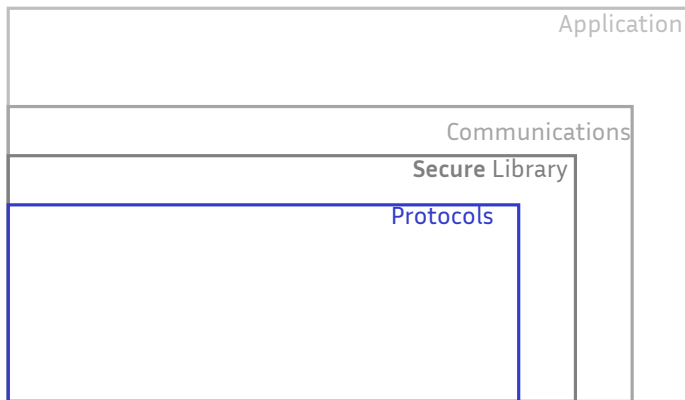
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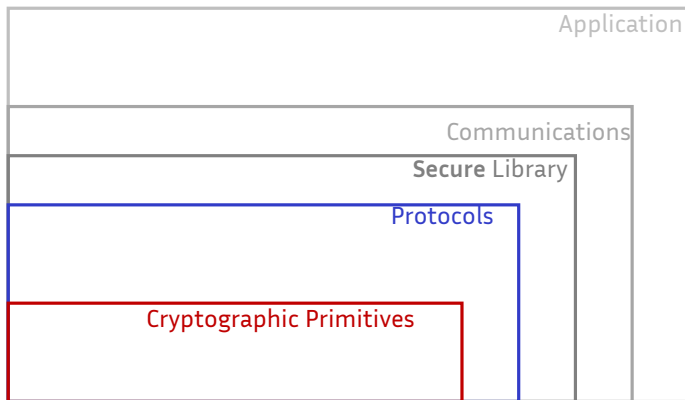
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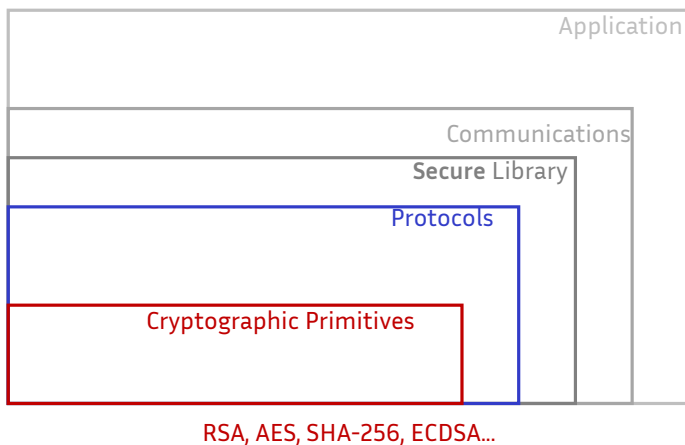
How Is It Used?



How Is It Used?



How Is It Used?



What Do Primitives Do?

A **cryptographic primitive** is a **basic building block** ; it has a very simple API but very sophisticated inner workings!

The block cipher

For any k -bit long key κ , E_κ is a **permutation** of $\{0, 1\}^n$.

Typically, $n \in \{64, 128\}$ and $k \in \{128, 256\}$.

To ensure **security**: no matter how many pairs $(x, E_\kappa(x))$ are known, it is impossible to recover κ ¹

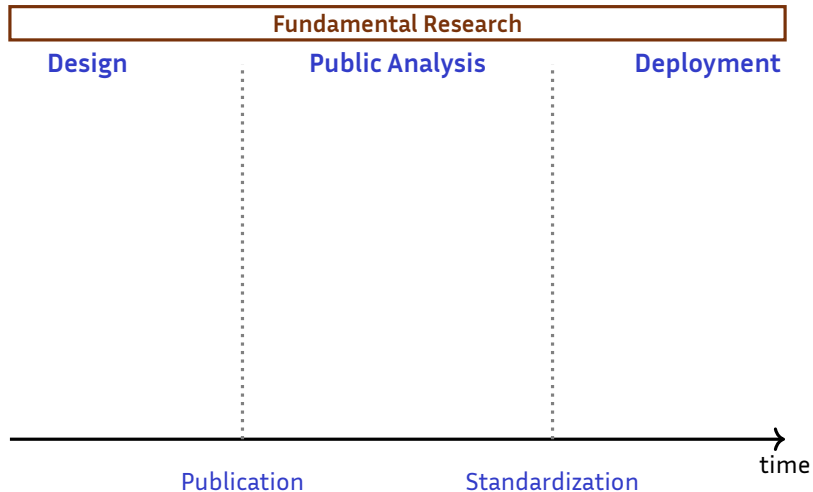
¹Except by trying all possible κ which has 2^k possible values.

How are the **primitives** used in practice chosen?

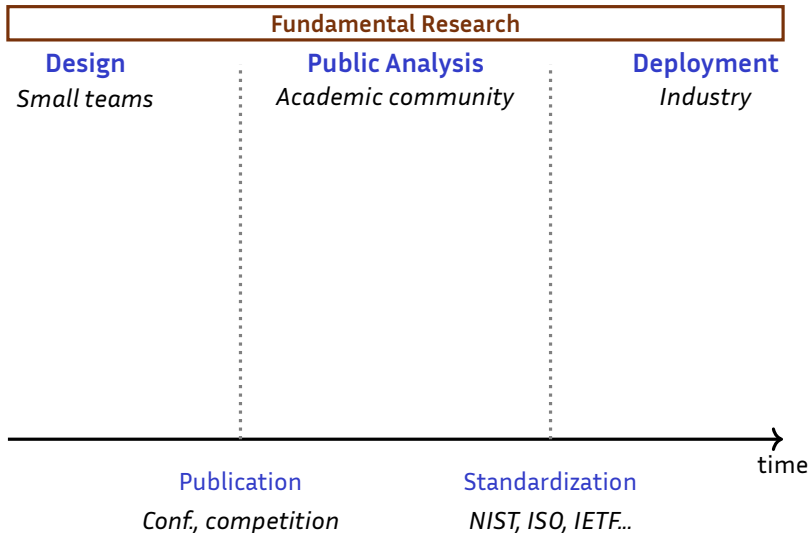
Life Cycle of a Cryptographic Primitive

Fundamental Research

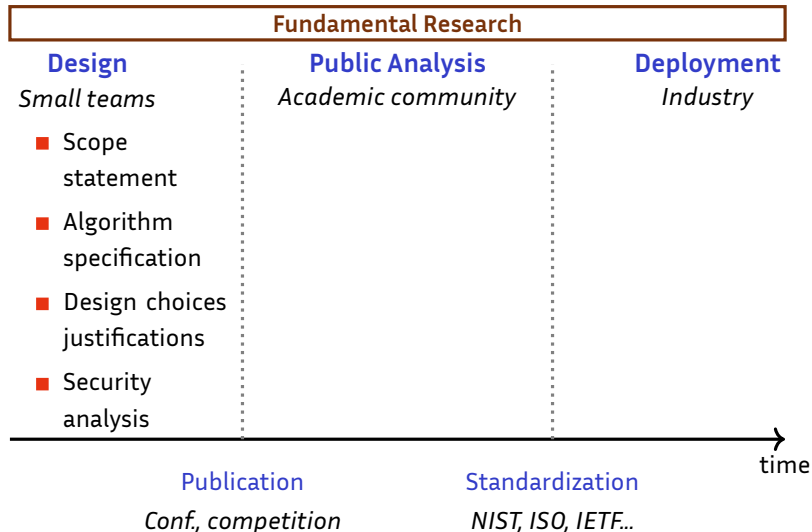
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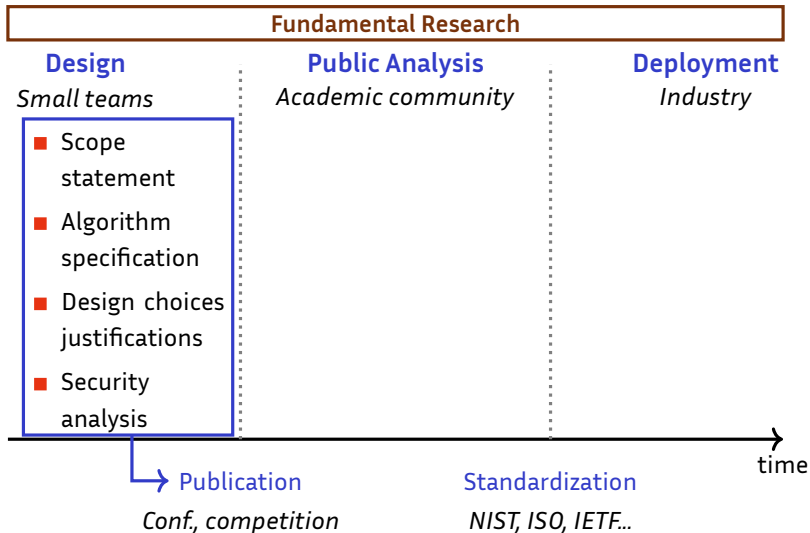
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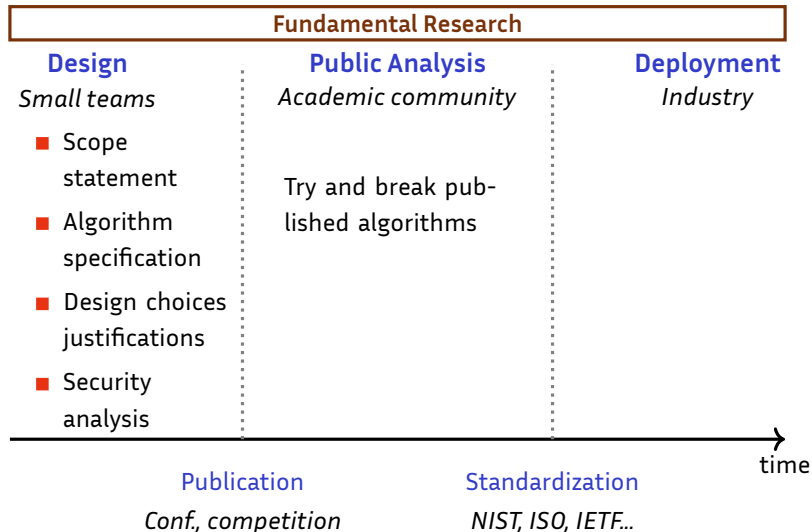
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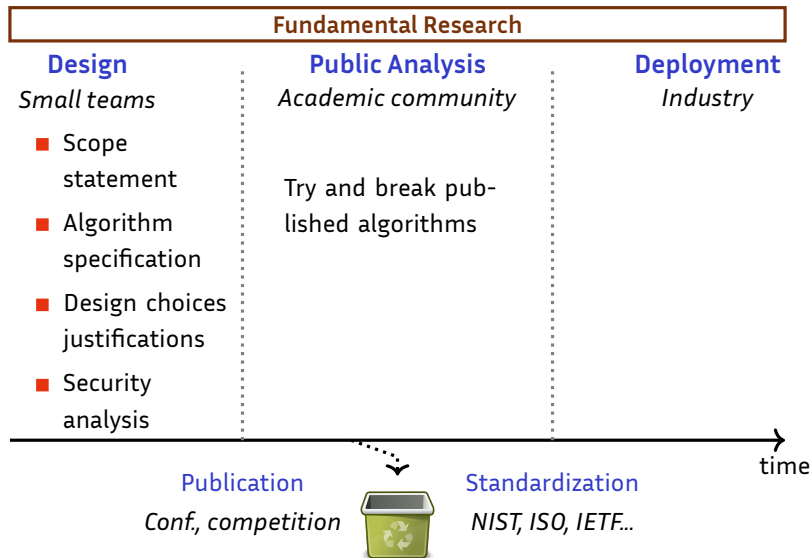
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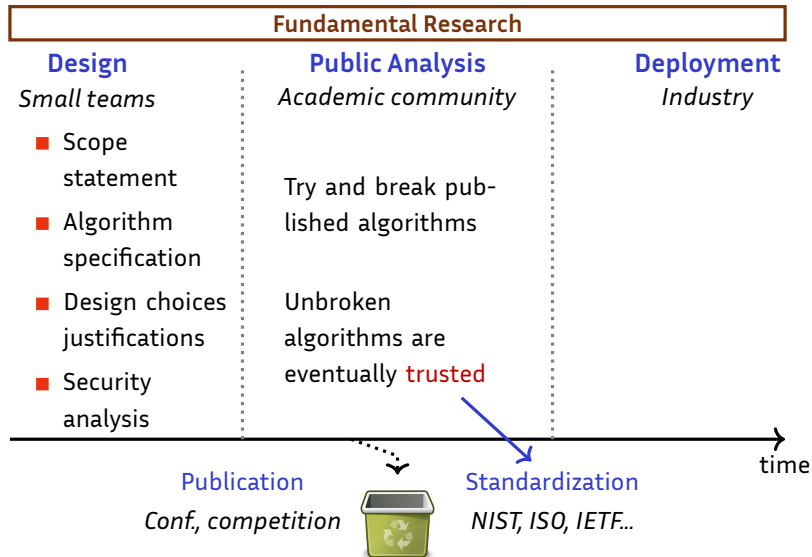
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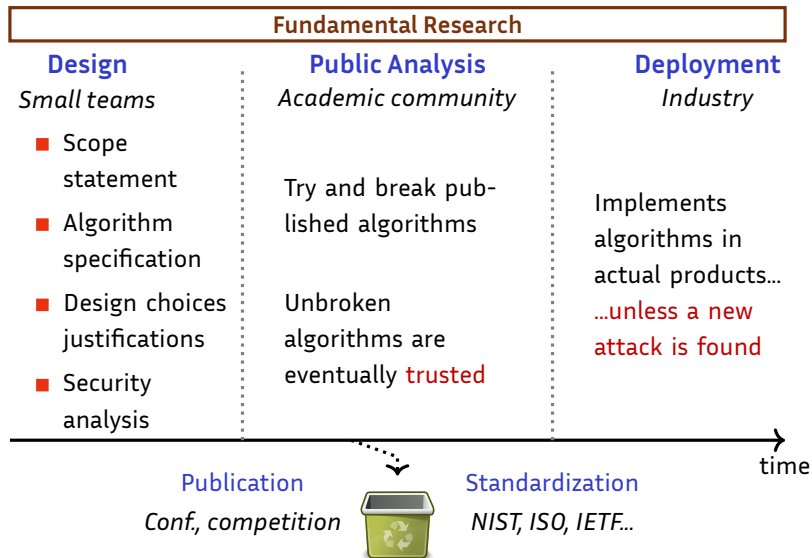
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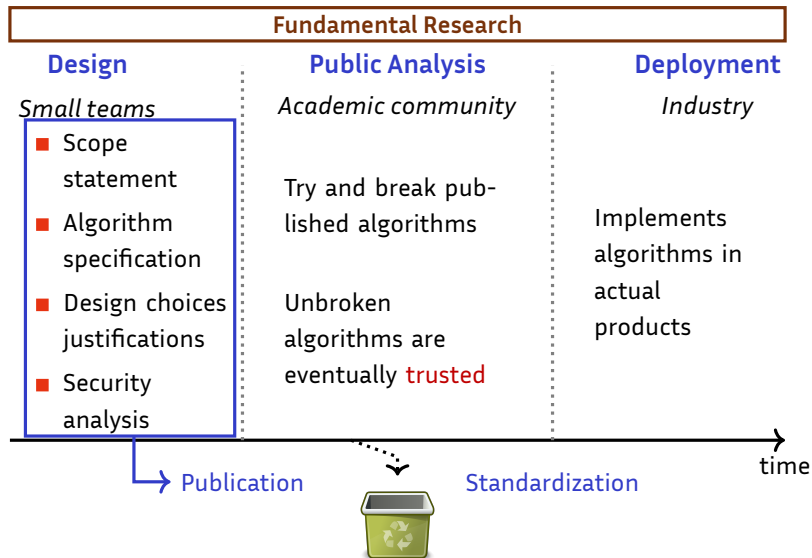
Life Cycle of a Cryptographic Primitive



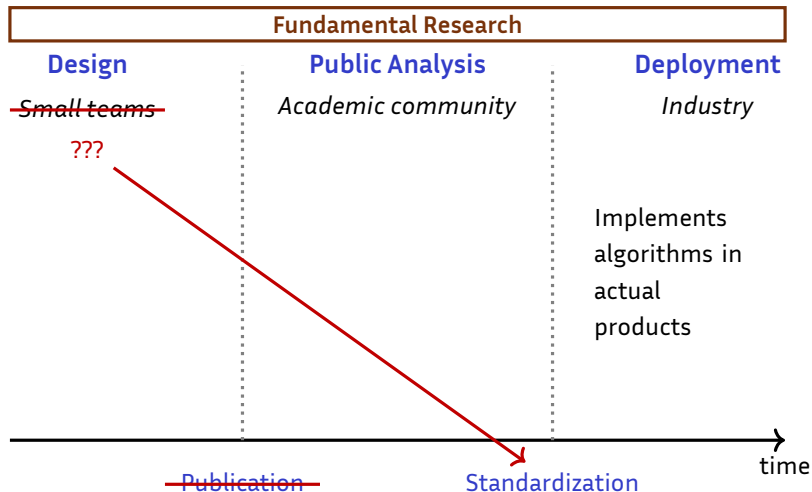
Life Cycle of a Cryptographic Primitive



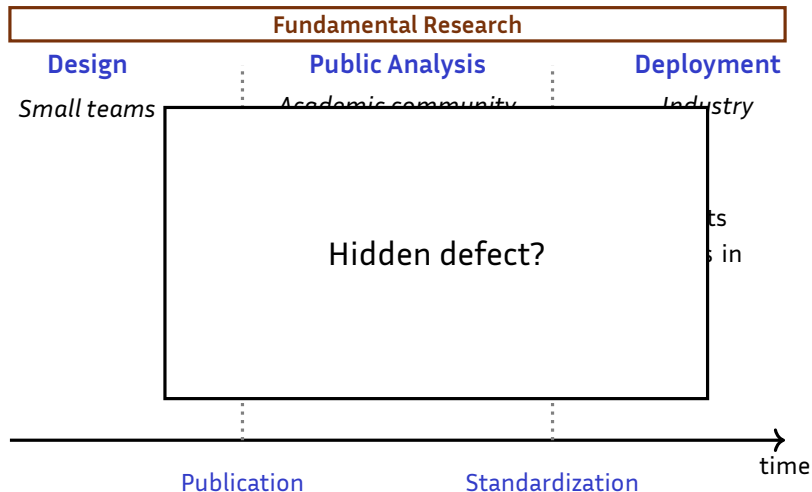
Breaking the Pipeline



Breaking the Pipeline



Breaking the Pipeline



Primitives we designed
Primitives we attacked

Primitives we designed

Primitives we attacked

Post-Quantum Public Key

The screenshot shows the NIST CSRC website. At the top is the NIST logo and a search bar labeled 'Search CSRC'. Below this is a blue banner with 'Information Technology Laboratory' and 'COMPUTER SECURITY RESOURCE CENTER' in white text, with the CSRC logo on the right. A green 'PROJECTS' button is visible. The main heading is 'Post-Quantum Cryptography' with social media icons for Facebook, Google+, and Twitter. Under 'Project Overview', it states that NIST has initiated a process to standardize quantum-resistant algorithms, with details in the 'Post-Quantum Cryptography Standardization page'. It mentions that 'Round 2 candidates' were announced in January 2019 and that the 'NISTIR 8240, Status Report on the First Round of the NIST Post-Quantum Cryptography Standardization Process' is now available. On the right, a 'PROJECT LINKS' sidebar lists 'Overview', 'FAQs', 'News & Updates', and 'Events'.

Quantum computers will **break** current public key algorithms

⇒ we need new algorithms!

Cosmiq Involvement

3 Cosmiq candidates made it to the second round! (**Bike, Classic McEliece, and Rollo**)

Ligthweight Secret Key

The screenshot shows the NIST CSRC website for the Lightweight Cryptography project. The header includes the NIST logo, 'Information Technology Laboratory', 'COMPUTER SECURITY RESOURCE CENTER', and the CSRC logo. A search bar is in the top right. Below the header, a green 'PROJECTS' button is visible. The main heading is 'Lightweight Cryptography', followed by social media icons for Facebook, Google+, and Twitter. The 'Project Overview' section contains a paragraph about emerging areas like sensor networks and IoT. To the right, a 'PROJECT LINKS' sidebar lists 'Overview', 'News & Updates', and 'Events'.

NIST
Information Technology Laboratory
COMPUTER SECURITY RESOURCE CENTER
CSRC

Search CSRC

PROJECTS

Lightweight Cryptography

f G+ t

Project Overview

There are several emerging areas (e.g. sensor networks, healthcare, distributed control systems, the Internet of Things, cyber physical systems) in which highly-constrained devices are interconnected, typically communicating wirelessly with one another, and working in concert to accomplish some task. Because the majority of current cryptographic algorithms were designed for desktop/server environments, many of these algorithms do not fit into constrained devices.

PROJECT LINKS

- Overview
- News & Updates
- Events

IoT devices cannot handle the (low!) **complexity** of current symmetric ciphers.

⇒ we need new algorithms!

Cosmiq Involvement

3 Cosmiq candidates made it to the second round! (Saturnin, Sparkle, Spook)

Primitives we designed
Primitives we attacked

Breaking SHA-1

SHA-1 is a **hash function**.

Collision Resistance

For a hash function H , it should not be possible to find messages x and y such that

$$H(x) = H(y) .$$

Cosmiq Involvement

It is possible **in practice** to find **meaningful** messages $a||x$ and $a||y$ where a and b are meaningful and such that

$$H(a||x) = H(a||y)$$

G. Leurent, T. Peyrin. *From Collisions to Chosen-Prefix Collisions – Application to Full SHA-1*. Eurocrypt 2019.

Finding Weird Patterns in Russian Standards

questioned is the S-box π . This S-box was chosen from Streebog hash-function and it was synthesized in 2007. Note that through many years of cryptanalysis no weakness of this S-box was found. The S-box π was obtained by pseudo-random search and the following properties were taken into account.

[...]

No secret structure was enforced during construction of the S-box. At the same time, it is obvious that for any transformation a lot of representations are possible (see, for example, a lot of AES S-box representations).

Cosmiq Involvement

The designers of Streebog and Kuznyechik **are lying**. The probability that a **random** S-box is as **structured** as theirs is $< 2^{-1000}$ (\approx winning the “loto” 60 times in a row).

Scientific publication: **X. Bonnetain, L. Perrin, S. Tian**. *Anomalies and Vector Space Search: Tools for S-box Analysis*. Asiacrypt 2019.

Conclusion

Cryptography is an **active** research area motivated by concrete needs for **standard** algorithms.

Conclusion

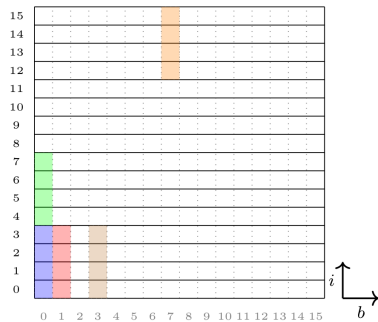
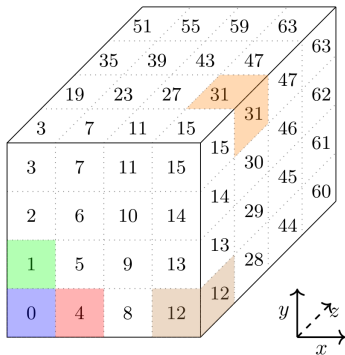
Cryptography is an **active** research area motivated by concrete needs for **standard** algorithms.

Thank you!

Delenda Russian Algo

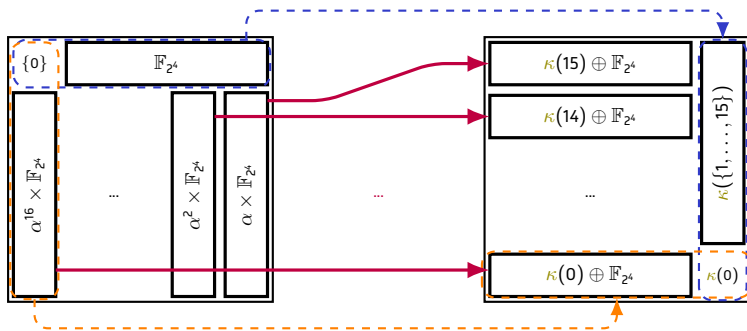
Appendix

Saturnin



The TKlog Structure

$$\pi : \begin{cases} \mathbb{F}_{2^8} & \rightarrow \mathbb{F}_{2^8} \\ 0 & \mapsto \kappa(0) \\ \alpha^{17j} & \mapsto \kappa(16 - j) \quad \text{for } 1 \leq j \leq 15 \\ \alpha^{i+17j} & \mapsto \kappa(16 - i) \oplus (\alpha^{17})^{s(j)} \quad \text{for } 0 < i, 0 \leq j < 16 \end{cases}$$



Definition

```
p(x){unsigned char*k="Q`rFTDVbpPB
vdtfRQ\xacp?\xe2>4\xa6\xe9{z\xe3q
5\xa7\xe8",a=2,l=0,b=17;while(x&&
(l++,a^x))a=2*a^a/128*29;return l
%b?k[l%b]^k[b+l/b]^b:k[l/b]^188;}
```

165 ASCII characters that fit on 7 bits: this program is 1155-bit long.

<https://codegolf.stackexchange.com/questions/186498/>

proving-that-a-russian-cryptographic-standard-is-too-structured

Let $P(S)$ be the bitlength of a C implementation of $S \in \mathfrak{S}_{2^n}$.

Definition (Kolmogorov Anomaly)

The **Kolmogorov Anomaly** of S for C is the opposite of the \log_2 of the probability that a random S-box has a C implementation at most as long as that of S .

Estimating the Kolmogorov Anomaly

How to estimate it?



- (≤ 1155) -bit C programs implementing 8-bit permutations
- (≤ 1155) -bit strings
- \mathfrak{S}_{2^8}

For π , we get:

$$\frac{\#(\leq 1155)\text{-bit C prog.}}{|\mathfrak{S}_{2^8}|} \leq \frac{\#(\leq 1155)\text{-bit strings.}}{|\mathfrak{S}_{2^8}|} = \frac{2^{1156} - 1}{256!} \approx 2^{-528},$$

meaning that the Kolmogorov anomaly of π for C is at least 528.