A perspective on standardization of advanced cryptography at NIST

Luís Brandão

Cryptographic Technology Group
National Institute of Standards and Technology
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Presentation at ACS'19
Advanced **C**ryptography **S**tandardization Workshop
August 18, 20**19** @ Santa Barbara, California, USA

Thank you to Lily Chen, Rene Peralta and Andy Regenscheid for provided feedback

Outline

1. NIST introduction
2. Threshold cryptography
3. Some considerations
4. Privacy-enhancing cryptography
5. Concluding remarks

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NIST basics

National Institute of Standards and Technology (NIST)

(National Bureau of Standards 1901–1988) $\rightarrow$ NIST 1988–present

- **Non-regulatory** federal agency (within the U.S. Department of Commerce)
- **Mission:** To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Aerial photo of Gaithersburg campus (source: Google Maps, August 2019)

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Wide spectrum of competences

- $\sim 6\text{–}7 \times 10^3$ workers (employees + associates)
- Two campuses (Maryland and Colorado)
- Five laboratories and two centers
- Labs $\rightarrow$ Divisions $\rightarrow$ Groups $\rightarrow$ Projects
- Standards, research and applications

Aerial photo of Gaithersburg campus (source: Google Maps, August 2019)

Labs, divisions, groups

Information Technology Laboratory (ITL)

advancing measurement science, standards, and technology through research and development in information technology, mathematics, and statistics.

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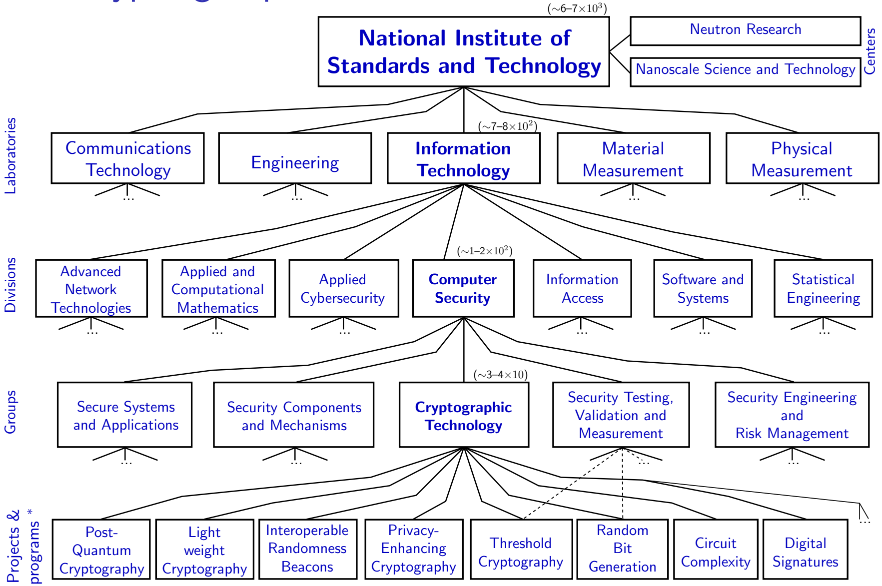
- Documents: "standards" (**FIPS**); recommendations, guidelines, reference material (**SP 800**); research reports and background information (**NISTIR**)
- International interaction: government, industry, academia, standardization

FIPS = Federal Information Processing Standards; SP 800 = Special Publications in Computer Security; NISTIR = NIST Internal or Interagency Report.

The “Crypto group” at NIST



* (Some projects/programs involve several groups, divisions or labs) (in parenthesis: approximate range # workers, inc. associates and fed. employees)

Some standardized crypto primitives

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- Block ciphers
- Cipher modes of operation
- Hash functions
- Signatures
- Pair-wise key agreement
- DRBGs

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- Block ciphers: DES (1977), EES (1994), TDEA (1999), AES (2001)
- Cipher modes of operation (1980–): CBC, CT, CCM, GCM ...
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(Not an exhaustive list; years indicated for perspective; some documentation has subsequent updates)
(Further details in “NIST Cryptographic Standards and Guidelines Development Program Briefing Book”)

Legend:

- AES = Advanced Encryption Standard
- CBC = Cipher block chaining (mode)
- CT = Counter (mode)
- CCM = Counter with Cipher-block chaining
- DES = Data Encryption Standard
- DH = Diffie–Hellman
- DSA = Digital Signature Algorithm
- DSS = Digital Signature Standard
- DRBG = Deterministic Random Bit Generator
- ECDSA = Elliptic curve DSA
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- EES = Escrowed Encryption Standard
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Several methods:

- Internal or interagency developed techniques
- Adoption of external standards
- Open call, competition, "competition-like"

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Development process:

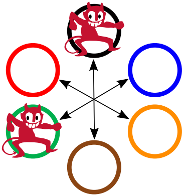
- NISTIR 7977: NIST Cryptographic Standards and Guidelines Development Process (2016). Formalizes several **principles** to follow:
  - transparency
  - openness
  - balance
  - integrity
  - technical merit
  - usability
  - global acceptability
  - continuous improvement
  - innovation and intellectual property

  (and overarching considerations)

Outline

NIST project: Threshold Cryptography

Goal: standardize threshold schemes for cryptographic primitives (signing, public-key decryption, key generation, enciphering, ...)



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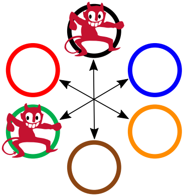

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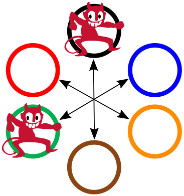

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- Potentially many standards ... which ones, what kind?
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- Different areas of expertise ... how to involve stakeholders?

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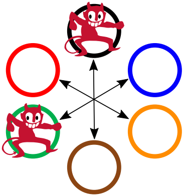

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Next slides: steps so far; some challenges; roadmap.

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NIST report on threshold schemes

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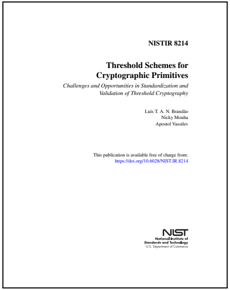
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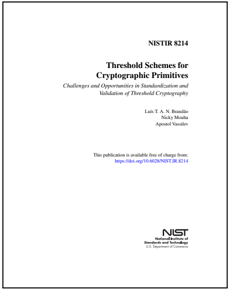
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(2 panels, 2 keynotes, 5 papers, 8 presentations,
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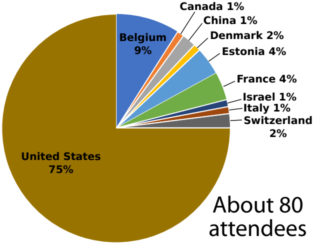

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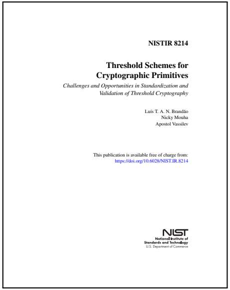
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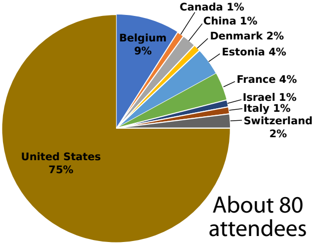

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- (Soon) **Draft roadmap towards standardization**
- (After) Get feedback on items for standardization and criteria for calls

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- separation of single-device vs. multi-party;
- usefulness of explaining rationale and envisioning applications;
- stakeholders' willingness to contribute;
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These elements are helpful for the next step ... designing a roadmap

Preliminary roadmap (ongoing)

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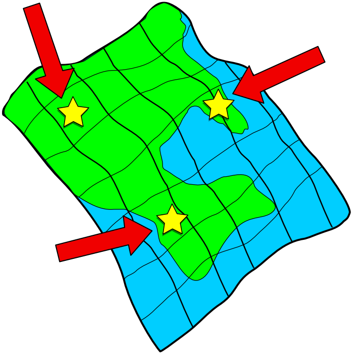

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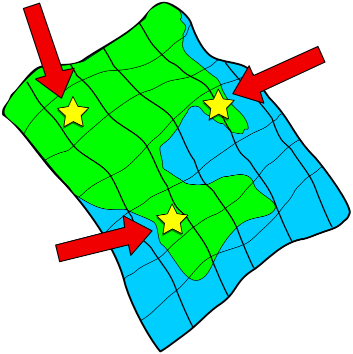

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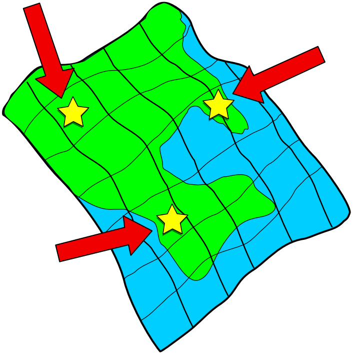

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Disclaimer: the structure in the next slides is subject to change.

Mapping layers

An abstract layered decomposition of the threshold standardization space

Four layers

Potential standardization space for threshold schemes for cryptographic primitives

Mapping layers

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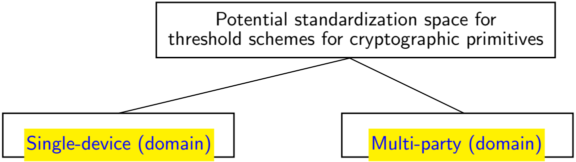
Four layers: domains



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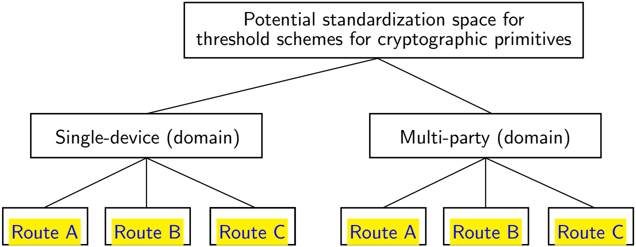

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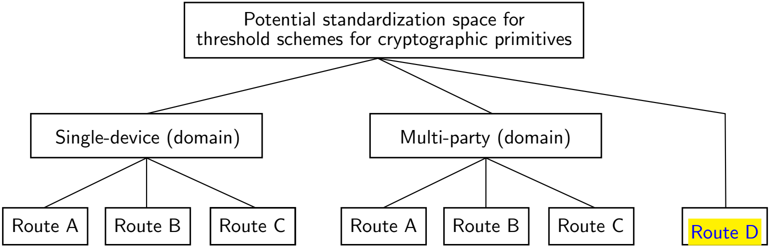

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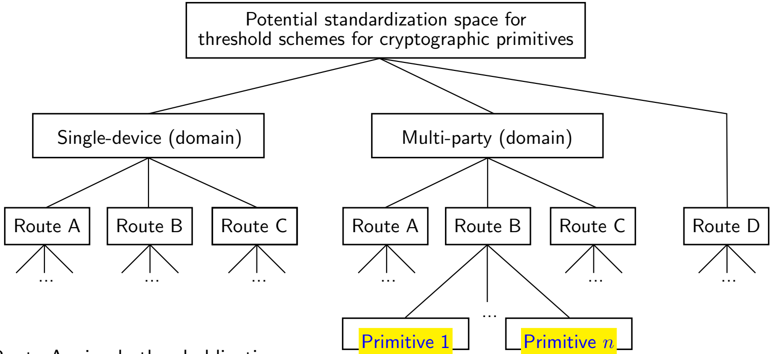

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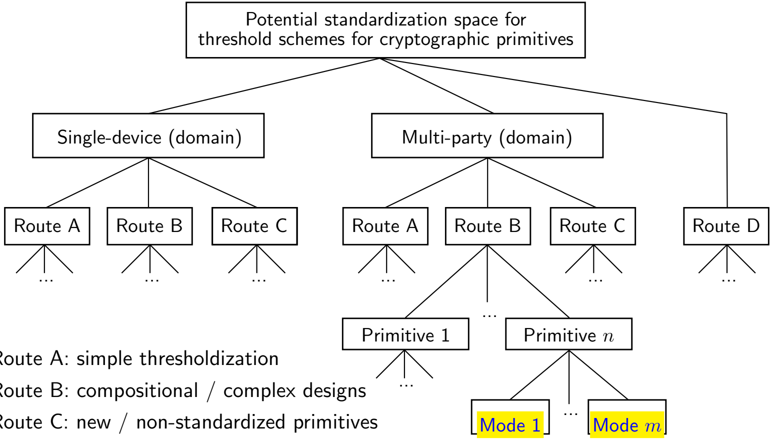

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- **B:**
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Examples of modes:

- **Interchangeable:** interface indistinguishable from conventional primitive (e.g., threshold signature with secret-shared key)
- **Secret-shared IO:** operation on secret-shared plaintext **i**nput (client sends shares of input separately to each component); similar for **o**utput
- **Auditable:** client can learn/prove that computation was thresholdized (e.g., multi-signature with independent keys)

Development process

Generic possible sequence of phases:

1. Roadmap → 2. Calls with criteria → 3. Evaluation → 4. Issue standards

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- **calls for contributions:** feedback on reference protocols; new protocols; reference implementations showing feasibility; research results, ...
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Public feedback can be useful for specifying:

- standardization *items* (down to the threshold mode / functionality);
- weighing factors: application motivation, validation suitability, features;
- features: rejuvenation, dynamic thresholds; robustness; composability; ...

Outline

A perspective on the granularity dilemma

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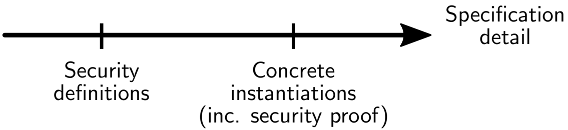

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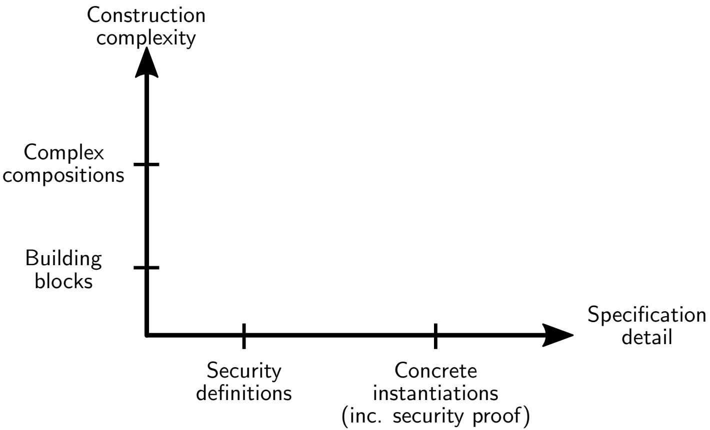

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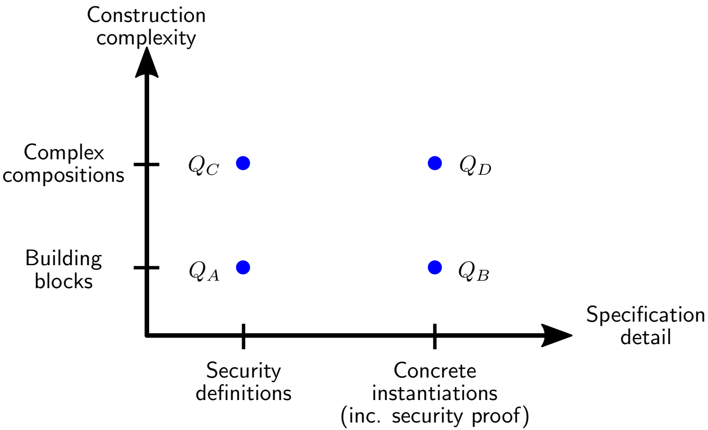

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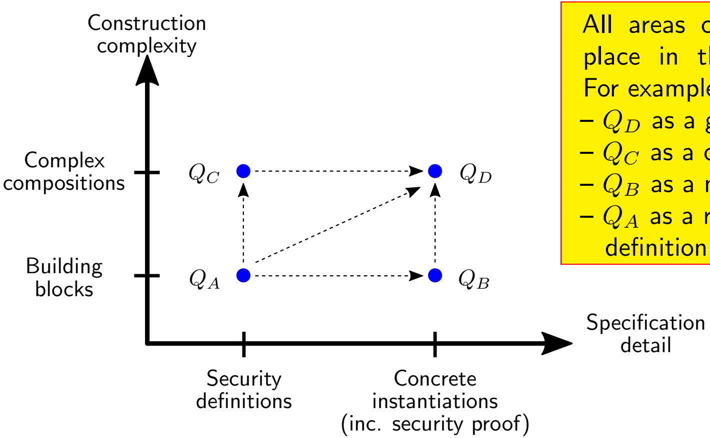
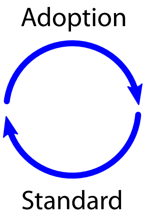


All areas can have a place in the process. For example:
- Q_D as a goal;
- Q_C as a criterion;
- Q_B as a module;
- Q_A as a reference definition.

Standardization vs. adoption

What makes a standard *good*? A well-done specification ... and the context.



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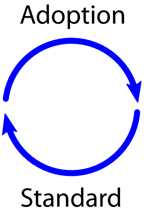

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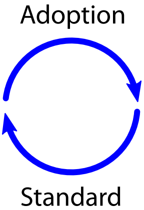

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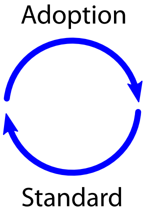

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Note: Adoption goals can vary with the standardization initiative

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Excerpt from NIST-ITL patent policy: "*assurance [...] that [...] party does not hold [...] any essential patent claim(s); or that a license [...] will be made available: under reasonable terms and conditions that are demonstrably free of any unfair discrimination;*" [possibly without compensation]

Excerpt from NISTIR 7977: "*NIST has noted a strong preference among its users for solutions that are unencumbered by royalty-bearing patented technologies. NIST has observed that widespread adoption of cryptographic solutions that it has developed has been facilitated by royalty-free licensing terms.*" [...]

"*NIST will explicitly recognize and respect the value of IP and the need to protect IP if it is incorporated into standards or guidelines.*"

Traceability / transparency

Make evident all the progress/changes in documentation.

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Make evident all the progress/changes in documentation. Example: a *diff* version shows the public comments and corresponding answers/changes.

rity model is not enough to assess the effects of ~~and on~~ placing a threshold scheme ~~placed~~ in an adversarial environment. One also needs to characterize implementation aspects whose variation may affect security. These include the types of threshold, the communication interfaces, the target computing platforms, and the setup and maintenance requirements. R14: N9

For example, system models and attack types can differ substantially across different platforms and communication mediums. It should thus be considered how the components inter-communicate, and how they can be assumed separate and independent vs. mutually interfering. In a single device setting, this may involve interaction between different components within a single chip or a single computer. In a contrasting setting, multiple nodes (e.g., R15: A6, E19

#	Ref	Old location	E: Comments by Christian Cachin; Hugo Krawczyk; Tal Rabin; Jason Resch; Chrysoula Stathakopoulou (IBM)	Related	Reply Notes	Rev
38	E19	Sec. 1	Communications Channels Among other things, we were very pleased to see the level of attention that this document dedicates to considerations of the communications channel and how that can impact the security properties of the resulting threshold system. We consider it crucial enough to merit some discussion in the introduction (pages 1-3) as the attack models and realistic schemes differ enormously whether communication and the N components are (a) modules on the same chip; (b) compo-	A6, E19, E20, E21	– **NOTE:** Attack models and security properties can vary substantially with the type of implementation platform and communication between nodes – **CHANGED:** In Sec. 1 (Introduction), mentioned this example after enumerating characterizing features.	R15

https://csrc.nist.gov/CSRC/media/Publications/nistir/8214/final/documents/nistir-8214-diff-comments-received.pdf

Outline

Privacy-Enhancing Cryptography

The NIST PEC project (revived in 2019):

- Interested in privacy promotable by cryptography
- Zero-knowledge proofs (ZKPs), secure multiparty computation (SMPC), ...
- Wants to keep up to date with, and support, external initiatives
- An important goal: develop useful **reference material**

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Reference material:

- **Assess** the state of things (feasibility, cost, ...) in a particular area
- **Motivate** application / proofs-of-concept in use-cases
- **Frame** the further development of standards, and future discussions
- **Enable** interoperability for companies that want to do things now

ZKPs / ZKProof

ZKProof (https://www.zkproof.org):

- effort towards the standardization of zero-knowledge proofs (ZKPs)
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- proposed an editorial process to develop a community reference
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In summary:

- This is one activity supporting advanced cryptography standardization
- We also want to promote SMPC (...)

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What makes it advanced (regarding standardization)?

- Protocols (with distributed systems) instead of single-side primitives?
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Call for collaboration. We want to collaborate with open and transparent processes towards standardization of advanced cryptography. Let us know.

Concluding remarks

1. NIST is interested in the development of "advanced cryptography" (secure implementations, technology adoption, interoperability)
2. The standardization **development process** matters
3. Not everything should be standardized by NIST ... but some things should
4. The set of final standards can be of several types
5. Standardization considerations go beyond technical security
6. Humans are in the equation ... collaboration inter-stakeholders is essential
7. NIST is currently active in threshold crypto and PEC

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Photo in 1948 *

Photo in 2018: https://www.nist.gov/sites/default/files/documents/2018/06/15/nist_gaithersburg_master_plan_may_7_2018.pdf

The NIST Stone Test Wall: "Constructed [in 1948] to study the performance of stone subjected to weathering. It contains 2352 individual samples of stone, of which 2032 are domestic stone from 47 states, and 320 are stones from 16 foreign countries."

* https://www.nist.gov/el/materials-and-structural-systems-division-73100/nist-stone-wall

Thank you for your attention

A perspective on standardization of advanced cryptography at NIST

Presentation at ACS'19
Advanced **C**ryptography **S**tandardization Workshop
August 18, 20**19** @ Santa Barbara, California, USA

Feedback is very much appreciated

luis.brandao@nist.gov

List of Frames