Update on Standardization of Ascon family

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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Third NIST Workshop on Block Cipher Modes of Operation
October 3 – 4, 2023

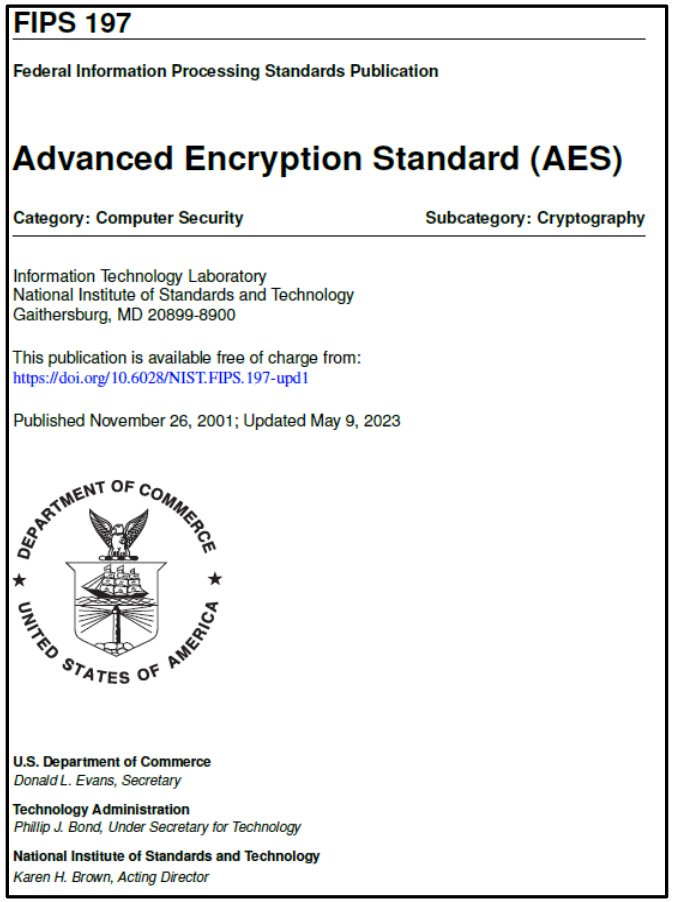
This Talk will cover

an overview of the NIST lightweight cryptography standardization

an update on standardization of Ascon family

Advanced Encryption Standard (AES)

- FIPS 197 Advanced Encryption Standard – Published in 2001.
- Reviewed[1] after 20 years and updated in May 2023.
- Widely adopted, with significant impact on economy[2]
- Instantiated with a *mode of operation* from SP 800-38 series (e.g., CBC, OFB, CBC, GCM, …)



FIPS 197

Federal Information Processing Standards Publication

Advanced Encryption Standard (AES)

Category: Computer Security **Subcategory: Cryptography**

Information Technology Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-8900

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Phillip J. Bond, Under Secretary for Technology

National Institute of Standards and Technology
Karen H. Brown, Acting Director

1. NIST IR 8319 & Publication Reviews https://csrc.nist.gov/projects/crypto-publication-review-project/completed-reviews
2. Leech et al., *The Economic Impacts of the Advanced Encryption Standard*, 2018

Why do we need more symmetric-key primitives?

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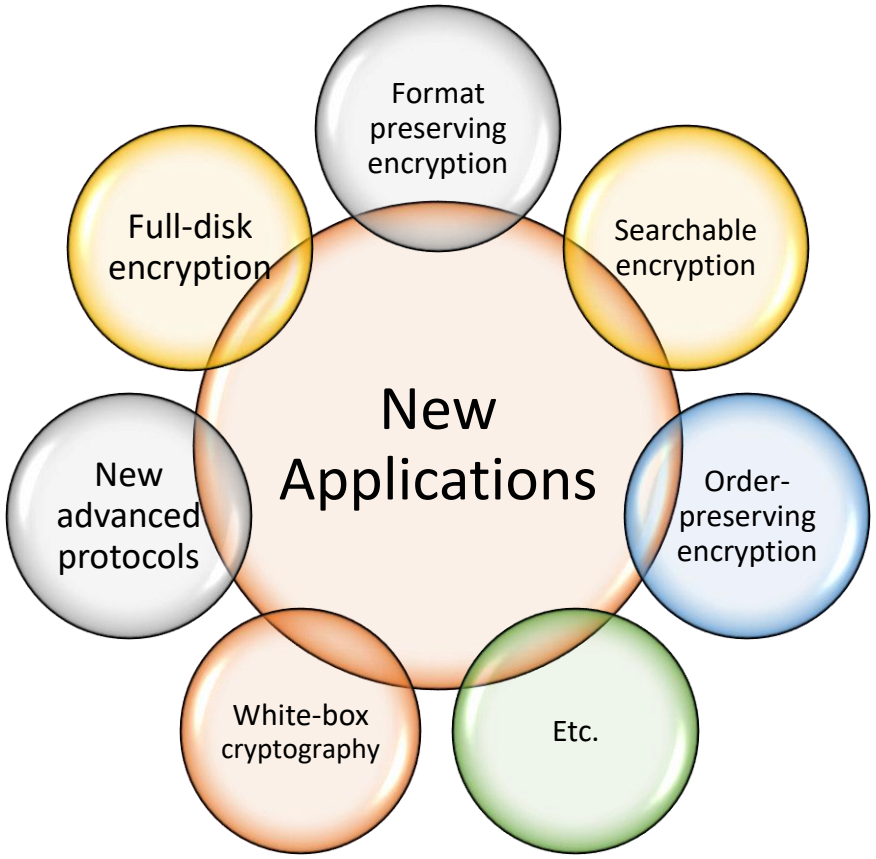
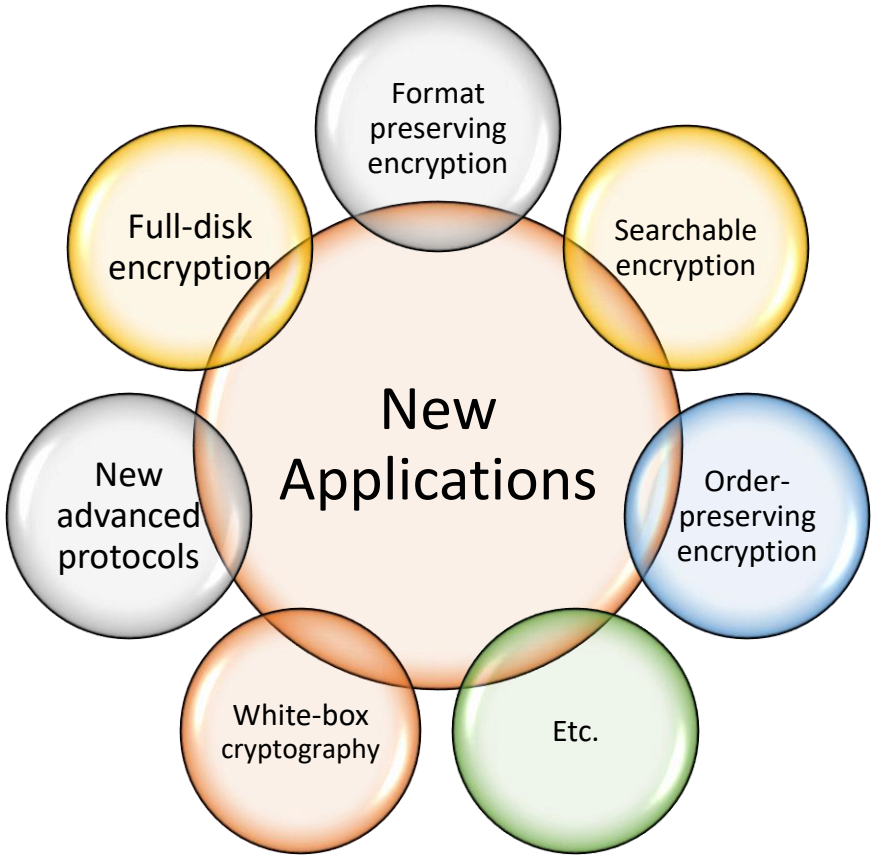
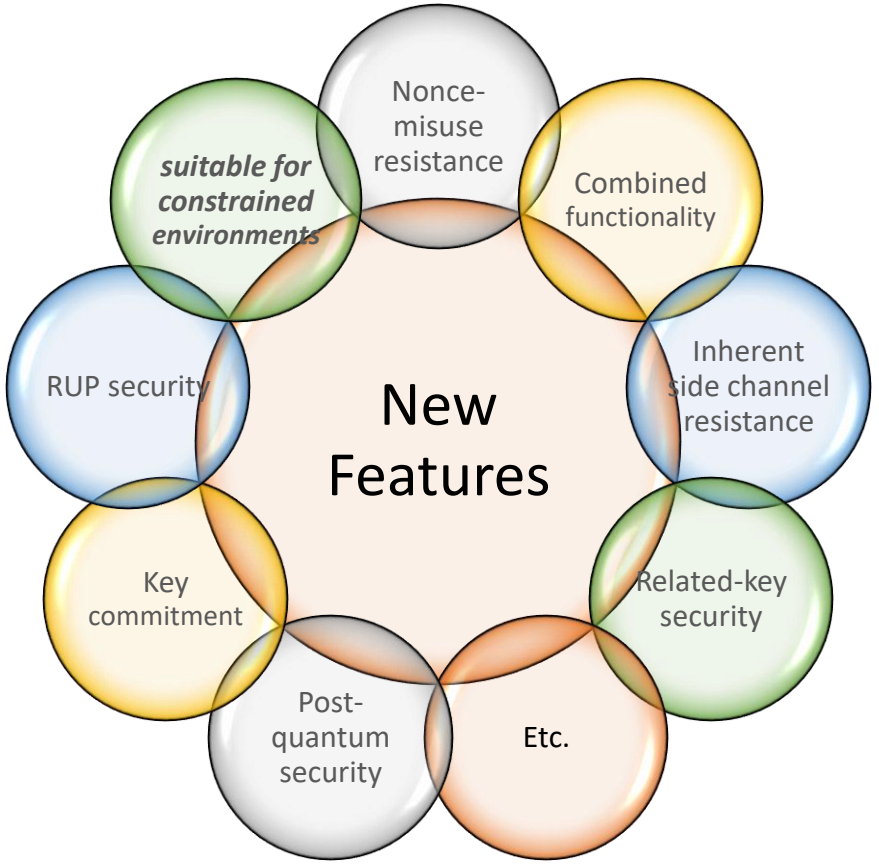
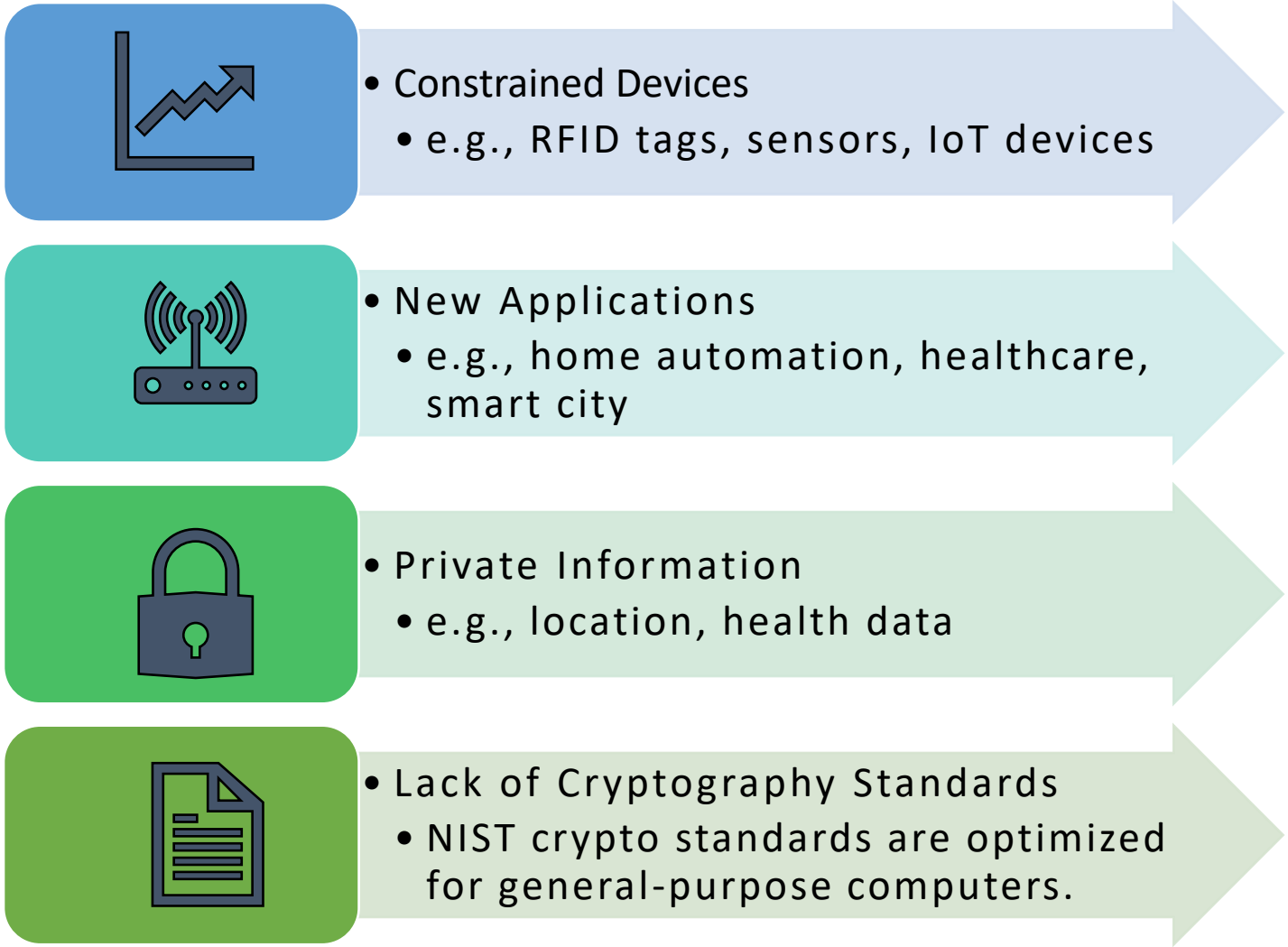


Why do we need more symmetric-key primitives?






• Constrained Devices
• e.g., RFID tags, sensors, IoT devices
• New Applications
• e.g., home automation, healthcare, smart city
• Private Information
• e.g., location, health data
• Lack of Cryptography Standards
• NIST crypto standards are optimized for general-purpose computers.

PROCESS

Public competition-like process with multiple rounds like AES, SHA3 and PQC standardization

GOAL

Develop new guidelines, recommendations and standards optimized for constrained devices

SCOPE

Authenticated Encryption and (optional) hashing for constrained software and hardware environments

Initial Phase
(July 2015 – August 2018)

Submission Call
(August 2018 – April 2019)

Round 1
(April 2019 – August 2019)

Round 2
(August 2019 – March 2021)

Final Round
(March 2021 – February 2023)

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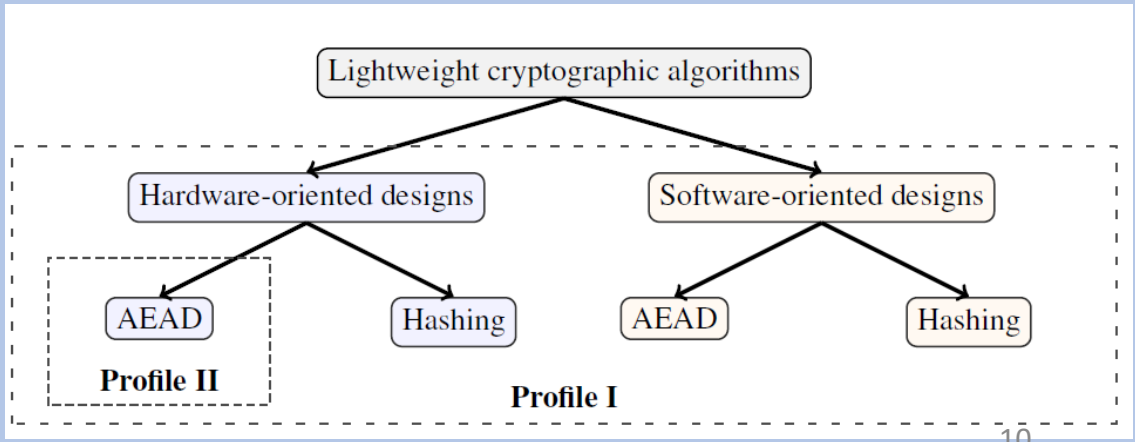
Workshops:

- First Lightweight Cryptography Workshop
  July 20 – 21, 2015
- Second Lightweight Cryptography Workshop
  October 17 – 18, 2016

to get feedback on target applications, industry need, requirements, etc.

Publications:

- NISTIR 8114 *Report on Lightweight Cryptography*
- (White paper, retired) *Profiles for the Lightweight Cryptography Standardization Process*



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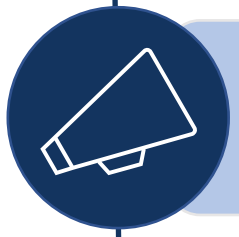

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In August 2018, NIST published '*Submission Requirements and Evaluation Criteria for the Lightweight Cryptography Standardization Process*'.

Submission deadline: February 2019

Security requirements

At least 112-bit security level for messages up to 2^{50} bytes, (nonce respecting). Key size at least 128 bits.

Design requirements

Perform better than NIST standards (AES-GCM, SHA-2), optimized for short messages etc.

Implementation requirements

Reference and optimized implementation compatible with API etc.

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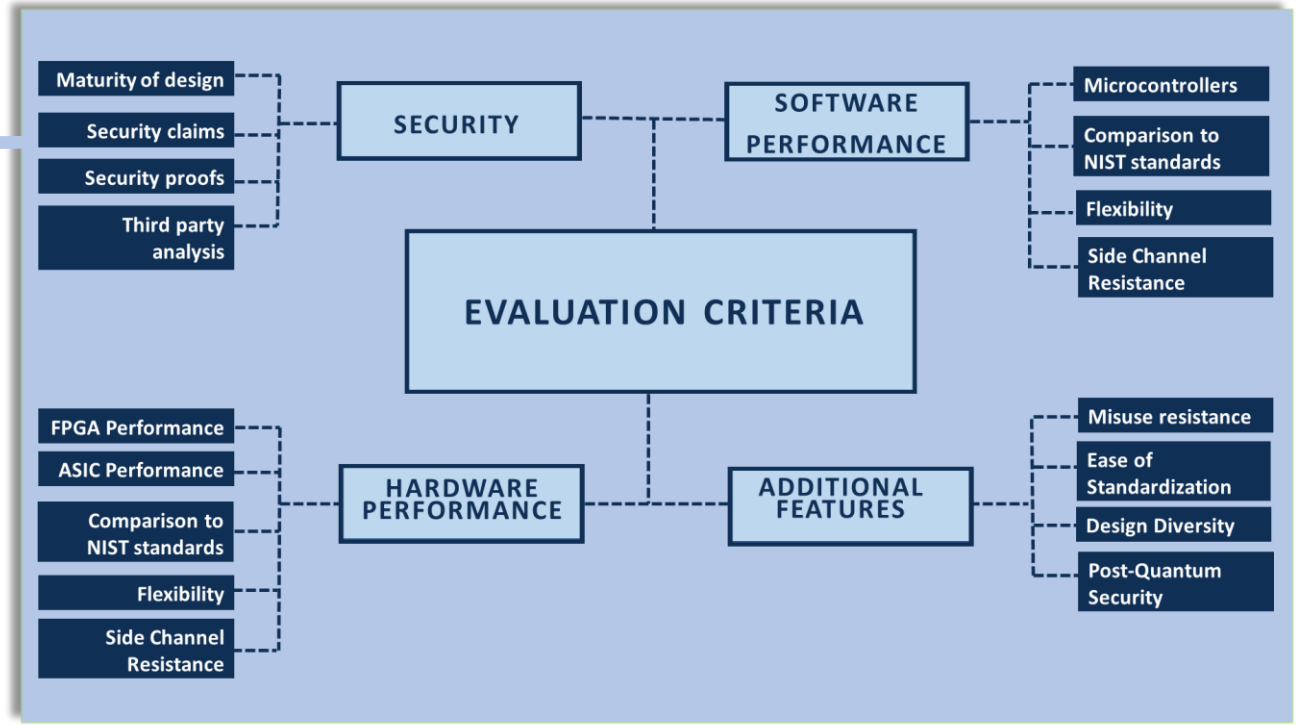

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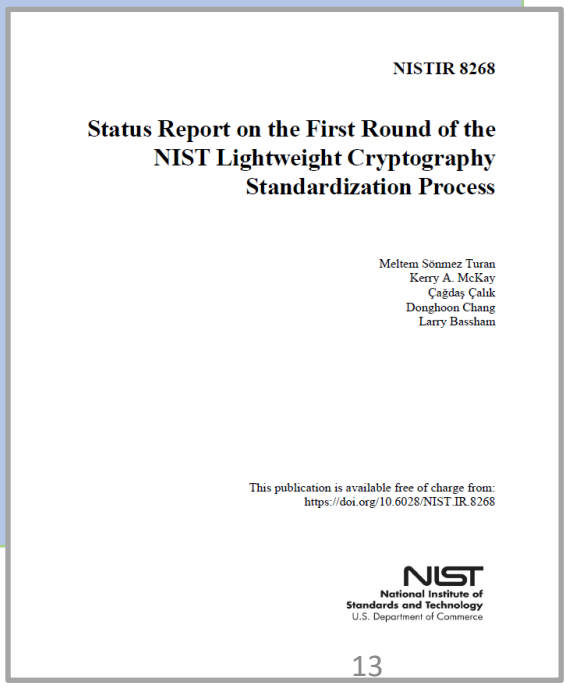
Around 4 months

56 First-round candidates

Evaluation of the candidates were done based on their security

- e.g., distinguishing attacks, practical tag forgeries, domain separation issues, new designs with no third-party analysis etc.

NIST IR 8268 explains how 32 candidates (out of 56) were selected to move forward to the second round.


NISTIR 8268

Status Report on the First Round of the NIST Lightweight Cryptography Standardization Process

Meltem Sönmez Turan
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Çağdaş Çalık
Donghoon Chang
Larry Bassham

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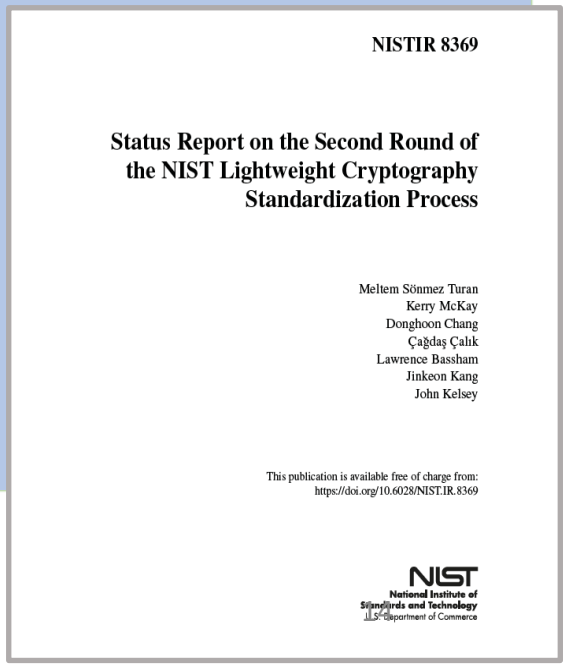
Around 20 months

32 Second-round candidates

Workshops:

- Third Lightweight Cryptography Workshop
  November 4 – 6, 2019
- Fourth Lightweight Cryptography Workshop 2016
  October 19 – 21, 2020

NIST IR 8369 explains how
10 finalists were selected
to move forward to
the final round.



NISTIR 8369

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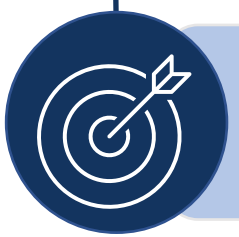


Final Round
(March 2021 – February 2023)

Evaluation of ten finalists took about 24 months.

Ascon	Photon-Beetle
Elephant	Romulus
GIFT-COFB	Sparkle
Grain-128AEAD	TinyJambu
ISAP	Xoodyak

Fair evaluation of finalists is challenging:

- Assigning different weights for different criteria
- Different security claims, different functionality, attacks with different complexities etc.
- Limited resources (not all algorithms got the same attention from the crypto community) for security analysis and benchmarking.

Decision relied on publicly available analysis and benchmarking results.

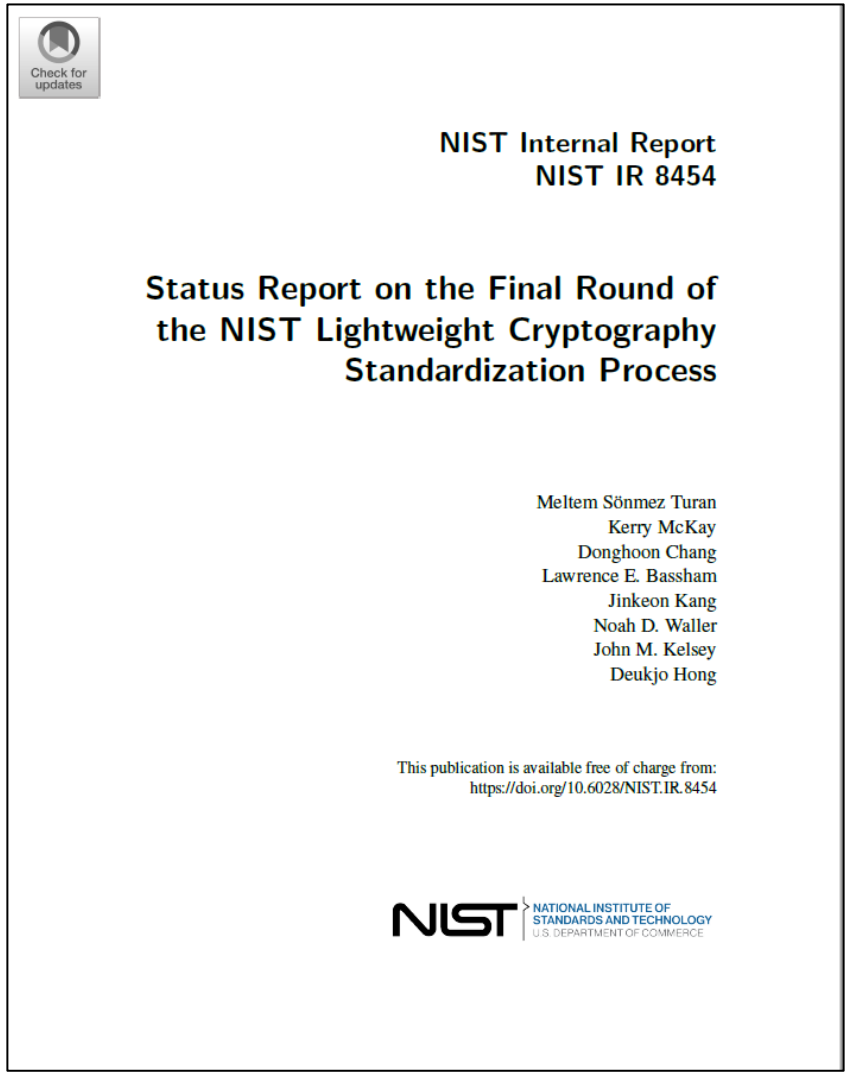
Finalists	*Variant*	*Building Block*	*Mode*	*Key size*	*Nonce Size*	*Tag Size*
ASCON	ASCON-128	ASCON Permutation	MonkeyDuplex	128	128	128
	ASCON-128a			128	128	128
	ASCON-80pq			160	128	128
Elephant	Dumbo	Spongent-π[160]	Encrypt-then-MAC	128	96	64
	Jumbo	Spongent-π[176]		128	96	64
	Delirium	KECCAK-f[200]		128	96	128
GIFT-COFB	GIFT-COFB	GIFT-128	Combined Feedback	128	128	128
Grain-128AEAD	Grain-128AEAD	Feedback shift register	Encrypt-and-MAC	128	96	64
ISAP	ISAP-A-128a	ASCON Permutation	Encrypt-then-MAC	128	128	128
	ISAP-K-128a	KECCAK-f[400]		128	128	128
	ISAP-A-128	ASCON Permutation		128	128	128
	ISAP-K-128	KECCAK-f[400]		128	128	128
PHOTON-Beetle	PHOTON-Beetle-AEAD[128]	PHOTON_{256} Permutation	Sponge with Combined Feedback	128	128	128
	PHOTON-Beetle-AEAD[32]			128	128	128
Romulus	Romulus-N	Skinny-128-384+ Tweakable Block Cipher	Combined Feedback	128	128	128
	Romulus-M		MAC-then-Encrypt	128	128	128
	Romulus-T		Encrypt-then-MAC	128	128	128
SPARKLE	SCHWAEMM256-128	SPARKLE_{384}	Sponge with Combined Feedback	128	256	128
	SCHWAEMM128-128	SPARKLE_{256}		128	128	128
	SCHWAEMM192-192	SPARKLE_{384}		192	192	192
	SCHWAEMM256-256	SPARKLE_{512}		256	256	256
TinyJAMBU	TinyJAMBU-128	Keyed Permutation	Sponge	128	96	64
	TinyJAMBU-192			192	96	64
	TinyJAMBU-256			256	96	64
Xoodyak	Xoodyakv1	Xoodoo Permutation	Sponge-variant Cyclist	128	128	128

Finalists	*Variant*	*Building Block*	*Mode*	*Digest size*
ASCON	ASCON-Hash ASCON-Hasha	ASCON Permutation	Sponge	256 256
PHOTON-Beetle	PHOTON-Beetle-Hash[32]	$PHOTON_{256}$ Permutation	Sponge	256
Romulus	Romulus-H	Skinny-128-384+	MDPH[1]	256
SPARKLE	ESCH256 ESCH384	$SPARKLE_{384}$ $SPARKLE_{512}$	Sponge	256 384
Xoodyak	Xoodyak	Xoodoo Permutation	Sponge	256

Selection of Ascon

In February 2023, NIST announced the Ascon family as the winner.

- High security margin, large number of third-party analysis (designed in 2014)
- Primary choice for the for lightweight applications in the final CAESAR portfolio (in 2019)
- No design tweaks
- Performance advantages over NIST standards (AES-GCM and SHA-2) in hardware and software
- Implementation and design flexibility
- Mode-level protection mechanism against leakage and lower additional cost for protected implementations
- Support for additional functionalities XOF, dedicated MAC, in addition to Hash


Check for updates

NIST Internal Report
NIST IR 8454

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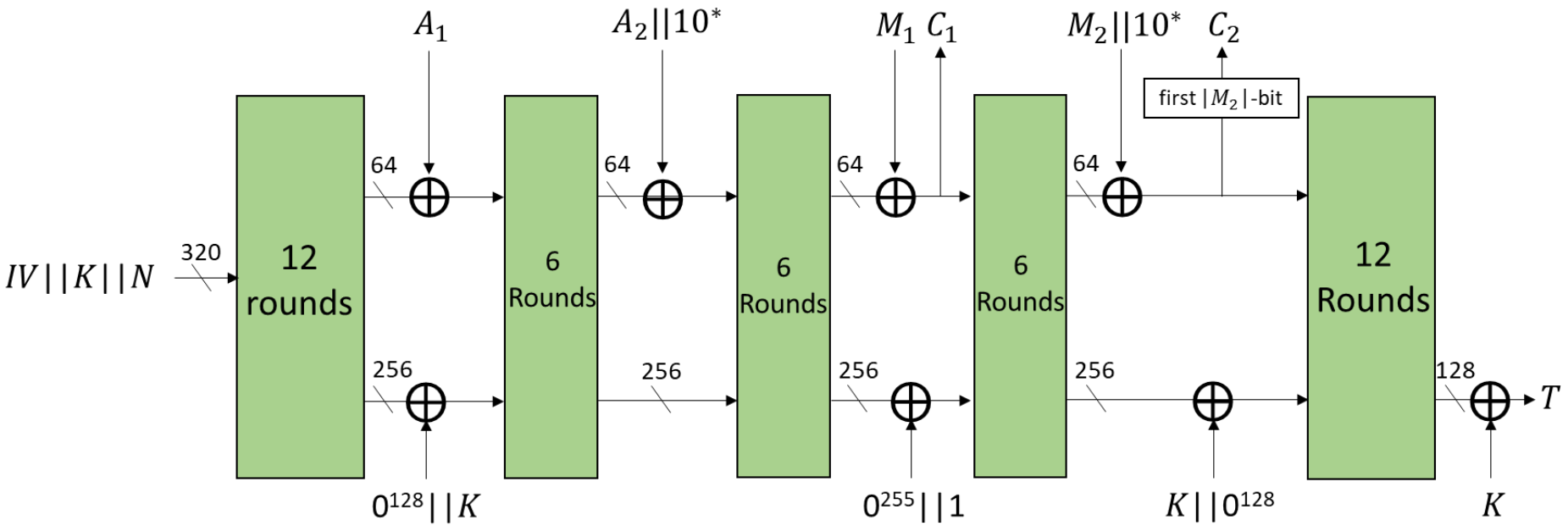
ASCON

- AEAD and hashing (fixed or variable output length) scheme
- Main component: 320-bit permutation instantiated with different constants and number of rounds for different variants
- AEAD: MonkeyDuplex mode with keyed initialization and finalization
- Hash: Sponge construction



The primary AEAD variant of Ascon family

Which variants to standardize?

	Variant	Parameter sizes
AEAD	**Ascon-128**	128-bit key/nonce/tag
	Ascon-128a	128-bit key/nonce/tag
	Ascon-80-pq	160-bit key, 128-bit nonce/tag
Hash	**Ascon-hash**	256-bit digest
	Ascon-hasha	256-bit digest
XOF	Ascon-XOF	Arbitrary length digest
	Ascon-XOFa	Arbitrary length digest

Current tentative decisions:

- Either Ascon-128 or both Ascon-128 and Ascon-128a
- Do not include Ascon-80pq
- XOF standardization instead of hash functions

Possible Updates

- Support of shorter tags: 64 and 96-bit tag
- Support for customization strings
- Little endian encoding of inputs for more efficient implementations
- Support for additional functionalities (PRF, MAC, KDF, DRBG etc.)
- How about key/context commitment, secret nonces ?

NEXT STEPS

- Publication of the draft standards describing the Ascon family (later in 2023)
  - Special Publication (SP) series rather than Federal Information Processing Standards (FIPS) (tentative decision)

- Public comments period of 60 to 90 days

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PUBLIC FORUM lwc-forum@list.nist.gov

GITHUB https://github.com/usnistgov/Lightweight-Cryptography-Benchmarking

WEBSITE https://csrc.nist.gov/Projects/lightweight-cryptography