Intro To Crypto On System z
Share 12687
San Francisco, CA February, 2013

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Agenda – Intro to Crypto

- **Some background**
  - Laws & Regulations
  - Crypto Standards
- **Crypto Functions**
- **Crypto Hardware**
- **Master Keys**
- **ICSF**
- **Linux**

Laws and Regs

- **Health Insurance Portability and Accountability Act of 1996 (HIPAA)**
- **California Senate Bill 1386**
- **Gramm-Leach Bliley Act (GLBA)**
- **Sarbanes-Oxley (SOX)**
- **Payment Card Industry Standards (PCI)**

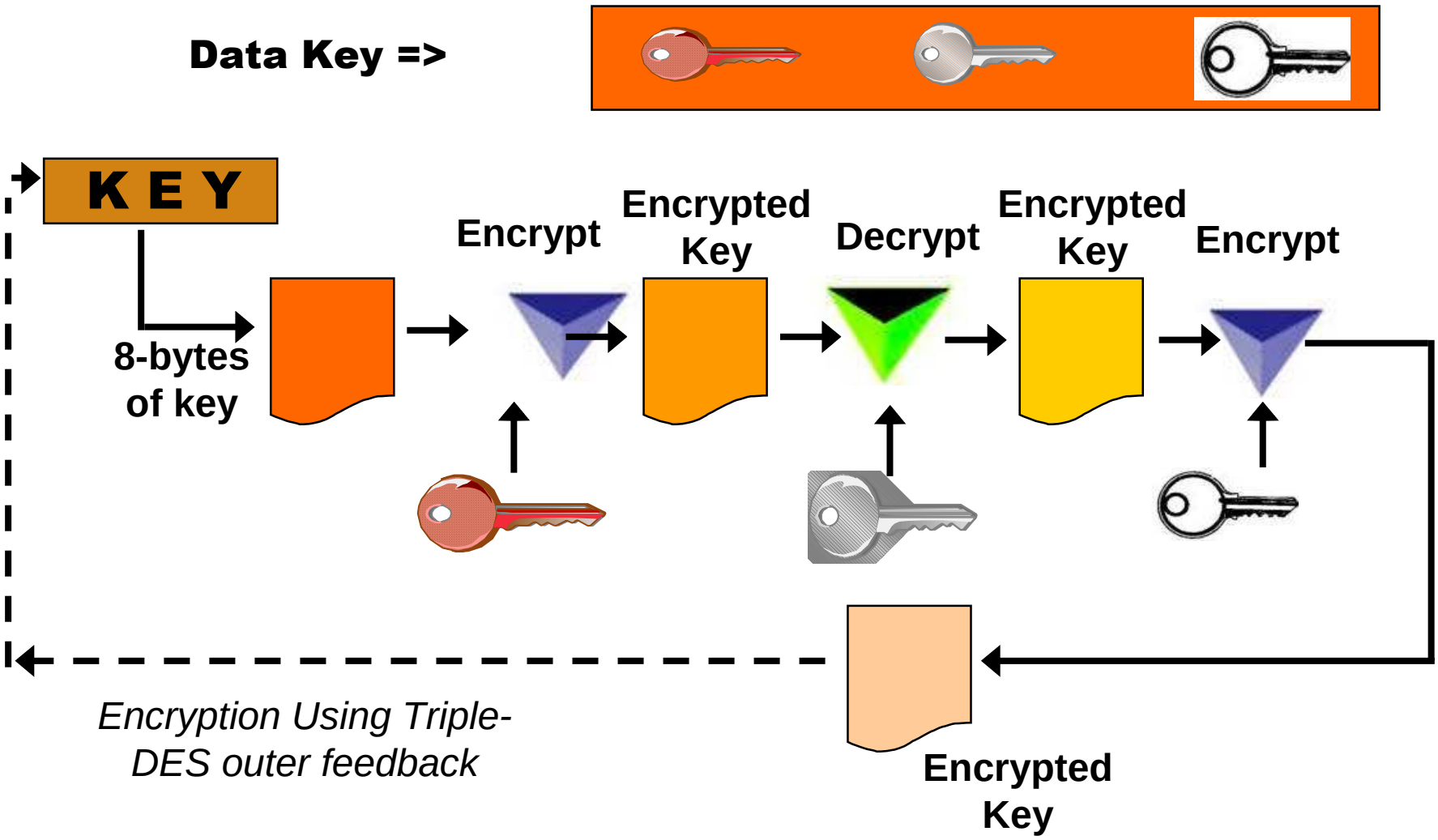
Cryptographic Standards

- **CCA (Common Cryptographic Architecture)**
- **PKCS (Public-Key Cryptography Standards)**
- **INTEL CDS (Common Data Security Architecture)**
- **OCSF (Open Cryptographic Services)**
- **ANSI (American National Standards Association)**
- **ISO (International Organization for Standardization)**
- **FIPS (Federal Information Processing Standards)**

Crypto Functions

- **Data Confidentiality**
  - Symmetric – DES/TDES, AES
  - Asymmetric – RSA, Diffie-Hellman, ECC
- **Data Integrity**
  - Modification Detection
  - Message Authentication
  - Non-repudiation
- **Financial Functions**
- **Key Security & Integrity**

Data Confidentiality – DES/TDES



Data Confidentiality - AES

- **Rijndael Algorithm**
  - Block Cipher (16-byte blocks)
  - 128-, 192, 256-bit Key Length
  - Multiple Rounds
  - Four Steps per Round (Byte Substitution, Shift Row, Mix Column, Add Round Key)

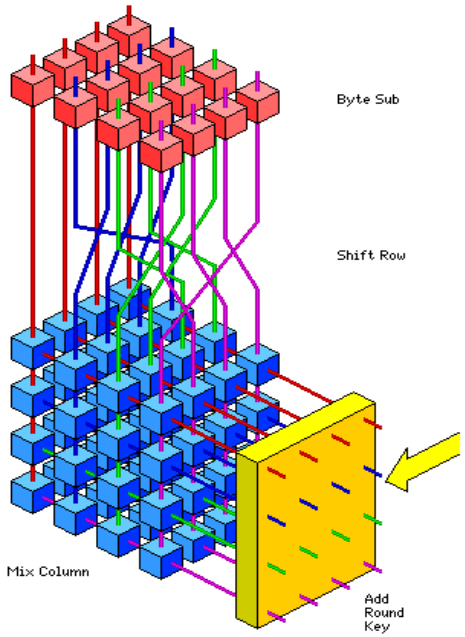
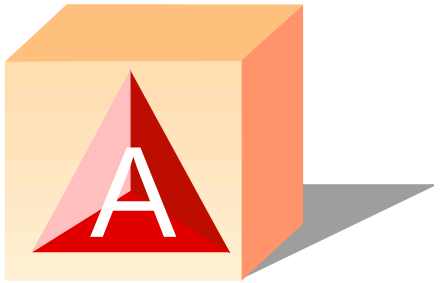
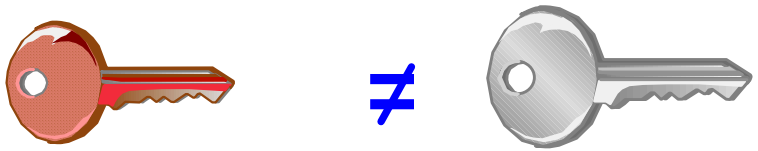


Image from http://www.esat.kuleuven.ac.be/~rijmen/rijndael/

Public Key Architecture - PKA

- **Asymmetric Keys**
  - RSA, Rivest Shamir and Adleman
  - Diffie-Hellman
  - Elliptic Curve (ECC)





Encipher Key ≠ **Decipher Key**

RSA Public Key Cryptography

▪ Generate 2 prime numbers	P = 7 Q = 17
(each over 100 digits long)	
▪ Multiply primes to get modulus, N	N = 7 x 17 = 119
▪ Select odd number, E, that will	E = 5
be the second part of the public key	
▪ **Public Key (N E) ➔**	**119 5**
▪ Compute second part of private key, D	
(P-1) x (Q-1) x (E-1)	(7-1) x (17-1) x (5-1) = 384
Add 1 to result	384 + 1 = 385
Divide by E to get D	D = 385/5 = 77
▪ **Private Key (N D) ➔**	**119 77**

Encipher Message ‘SELL’

- P = 7; Q = 17; N = 119; E = 5; D = 77

Public Key (N E) ➔ **119 5**

Private Key (N D) ➔ **119 77**

- Convert characters to numeric 19 5 12 12

E.g. a=1, b=2, c=3 ….

- Raise that character value to power E (‘S’ => 19**5 =>) 2476099
- Divide that by first part of Public Key to get the Modulus

2476099 MOD 119 = 66

$e_{PublicKey}$(S) => 66

- Ciphertext 66 31 3 3

Decipher Message ’66 31 3 3’

- P = 7; Q = 17; N = 119; E = 5; D = 77

Public Key (N E) ➔ **119 5**

Private Key (N D) ➔ **119 77**

- Raise ciphertext to power D — 66**77 = 1273160…..
- Divide result by first half of private key to get the modulus

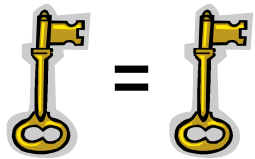
  1273160….. MOD 119 = 19
- Convert numeric back to character — 19 5 12 12

$d_{PrivateKey}$(66) => “S”

- Plaintext — 19 5 12 12 or C’S E L L’

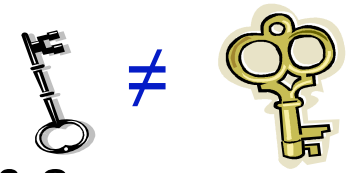
Why Symmetric and Asymmetric Keys?

- **Symmetric**



  - plus - less resource intensive
  - minus - requires key to be shared securely

- **Asymmetric**



  - plus - its strength, can be used to establish a secret between two parties
  - minus - expensive, regarding performance

Hash and Key Lengths

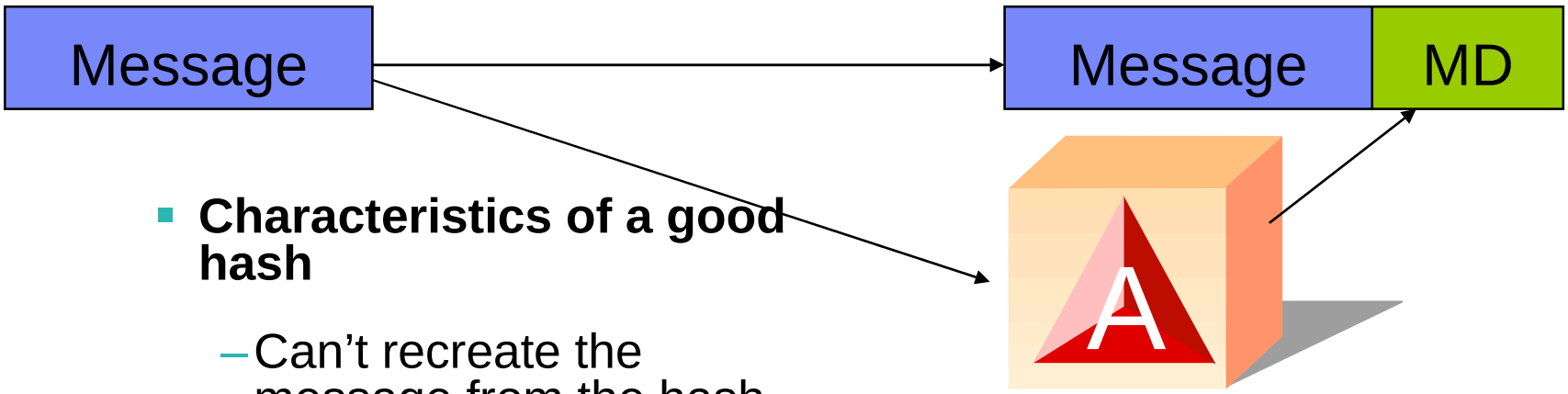
- **Why do we care about lengths a of keys and hashes?**
  - The longer a key the lower the probability to guess the right key
  - The longer a hash the lower the probability to guess a matching text for a given hash
  - Key and hash sizes that are considered secure change over time
- **Crypto Cryptography is not security, it is only low probability!? - But "Low" is "VERY LOW"!**
- **Examples of sizes:**

MegaMillions (March, 2012) @ $640Million	**1 In 176,000,000**
DES: 256 different keys	**1 in 72,057,594,037,927,936**
AES-128: 2^{128} different keys	**38 digits**
number of atoms in the earth	**about $1.33*10^{50}$**
number of atoms in our solar system	**about $1.2*10^{57}$**
AES-192: 2^{192} different keys	**58 digits**
AES-256/SHA-256: 2^{256} different keys/hashes	**77 digits**
number of atoms in the universe	**about 10^{82}**
SHA-512: 2^{512} different hashes	**154 digits**

- **Key lengths for symmetric keys are not comparable to those of asymmetric keys**
- **E.g. only a "few" numbers out of 2^{1024} 1024-bit numbers are valid keys for RSA**

Data Integrity – Modification Detection

Has the message changed?



- **Characteristics of a good hash**
  - Can't recreate the message from the hash
  - Two different messages are statistically unlikely to generate the same hash value

Hash Example

- **SHA1("The quick brown fox jumps over the lazy dog")**

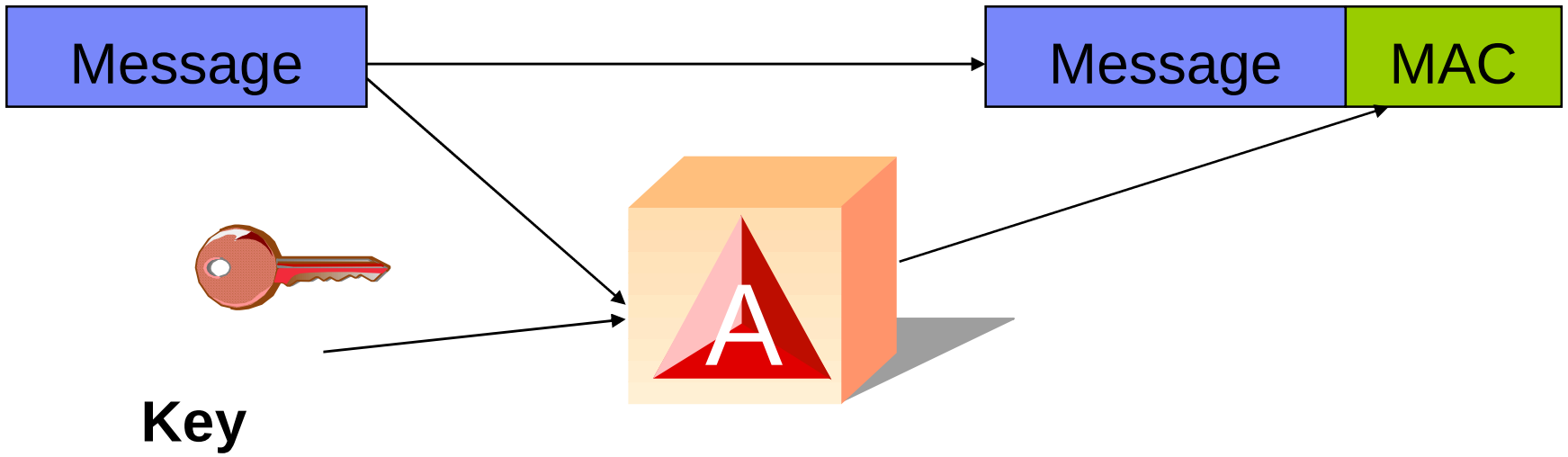
  = A9F1D770 4CA50AC1 504EA60B 12C7AE2D B054AD18

- **SHA1("The quick brown fox jumps over the lazy hog")**

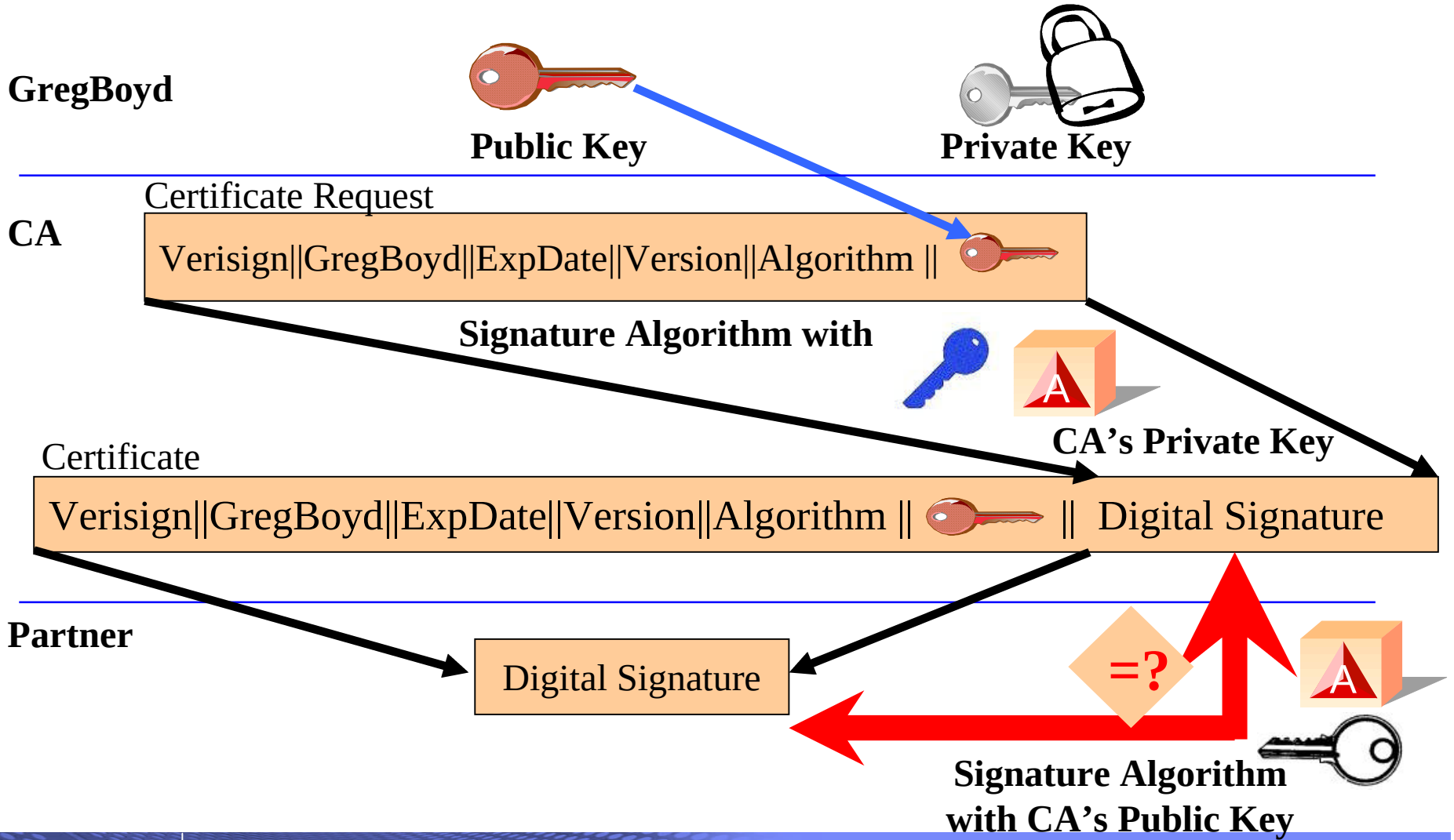
  =24120AD2 C337DE18 24E18BF0 C54F0B4F 98592343

Data Integrity – Message Authentication

Did the message come from who I think it came from?

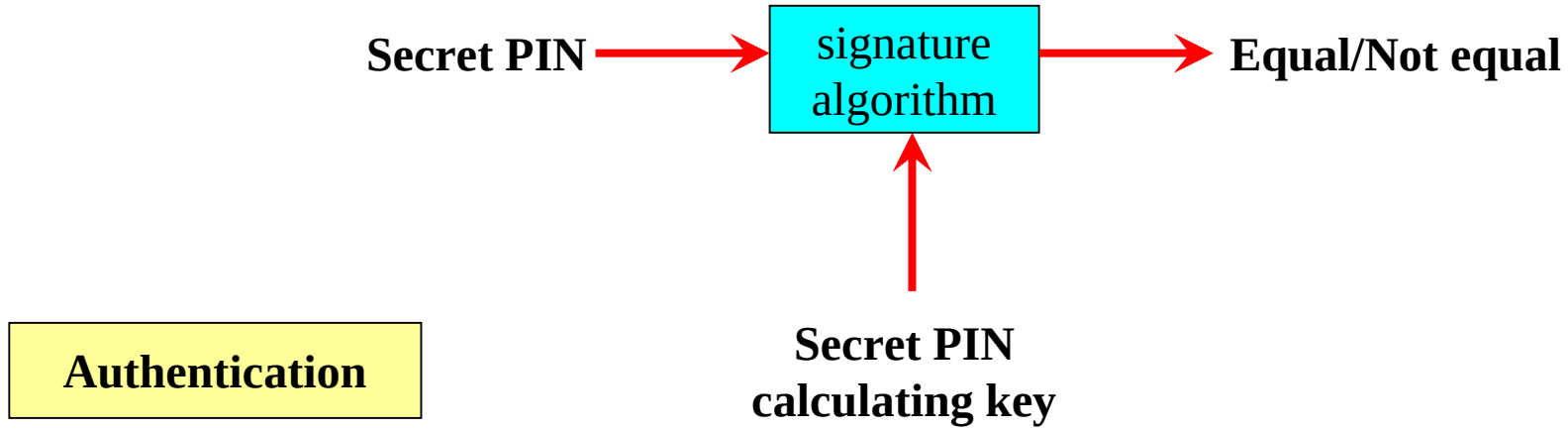


Data Integrity – Digital Certificates



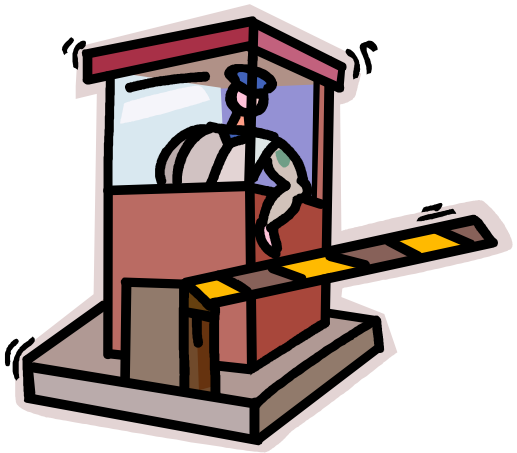
Financial Services

- **PIN Generation**
- **PIN Verification**
- **PIN Export/Import**



Suite B

- **Symmetric Encryption**
  - AES w/key sizes of 128 and 256
- **Digital Signatures**
  - ECDSA – Elliptic Curve, Digital Signature Algorithm
- **Key Agreement**
  - ECDH – Elliptic Curve, Diffie Hellman
- **Message Digest**
  - SHA-2 (SHA-256 and SHA-384)



http://www.nsa.gov/ia/programs/suiteb_cryptography/

Clear Key / Secure Key / Protected Key

- **Clear Key – key may be in the clear, at least briefly, somewhere in the environment**
- **Secure Key – key value does not exist in the clear outside of the HSM (secure, tamper-resistant boundary of the card)**
- **Protected Key – key value does not exist outside of physical hardware, although the hardware may not be tamper-resistant**

Protected Key – How it works

- **Create a key, with the value ‘ABCD’ and store it as a secure key in the CKDS (i.e. encrypted under the Master Key, MK)**
  - E_{MK}(x’ABCD’) => x’4A!2’ written to the CKDS and stored with a label of MYKEY
- **Execute CSNBSYE (the clear key API to encrypt data), but pass it the key label of our secure key, MYKEY; and text to be encrypted of ‘MY MSG ’**
  - CALL CSNBSYE(….,

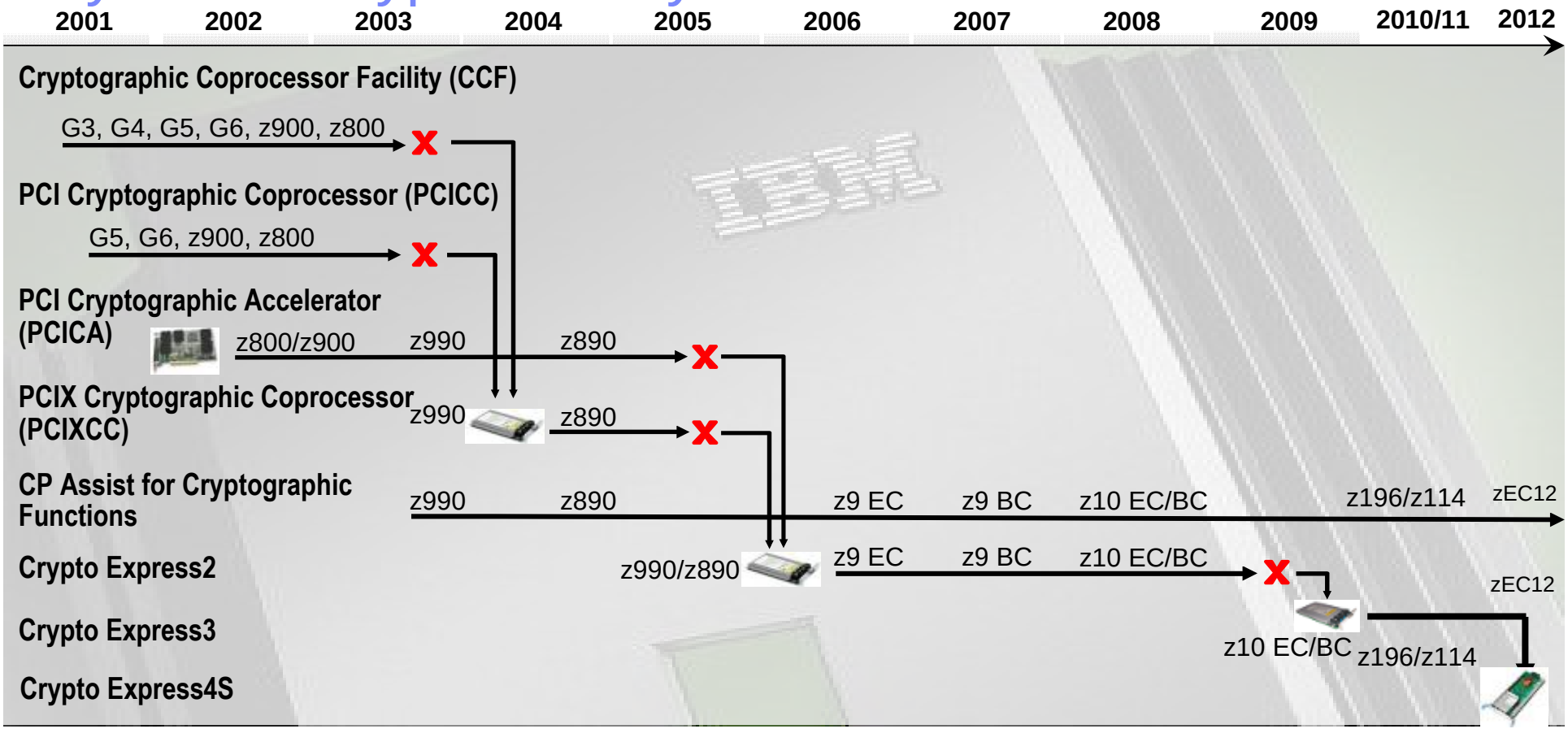
    MYKEY,

    ‘MY MSG ’ ….)

Protected Key – How it works (cont …)

- **ICSF will read MYKEY from the CKDS and pass the key value x'4A!2' to the CEX3**
- **Inside the CEX3, recover the original key value and then wrap it using the wrapping key**
  - D_{MK}(x' 4A!2') => x' ABCD'
  - E_{WK}(x'ABCD') => x'*94E'
- **ICSF will pass the wrapped key value of x'*94E' to the CPACF, along with the message to be encrypted**
- **In the CPACF, we'll retrieve the wrapping key, WK**
  - D_{wk}(x'*94E') => x'ABCD'
  - $E_{x'ABCD'}$('MY MSG ') => ciphertext of x'81FF18019717D183'

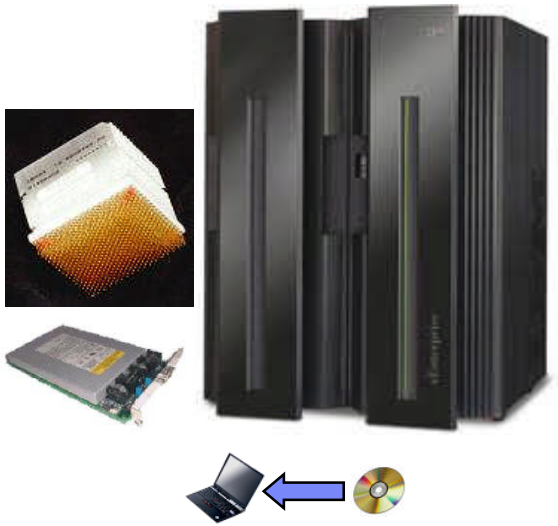
System z Crypto History



- Cryptographic Coprocessor Facility – Supports “Secure key” cryptographic processing
- PCICC Feature – Supports “Secure key” cryptographic processing
- PCICA Feature – Supports “Clear key” SSL acceleration
- PCIXCC Feature – Supports “Secure key” cryptographic processing
- CP Assist for Cryptographic Function allows limited “Clear key” crypto functions from any CP/IFL
  - NOT equivalent to CCF on older machines in function or Crypto Express2 capability
- Crypto Express2 – Combines function and performance of PCICA and PCICC
- Crypto Express3 – PCIe Interface, additional processing capacity with improved RAS
- Crypto Express4S - IBM Standard PKCS #EP11

System z Clear Key Crypto Hardware – z9 (EC & BC), *z10 (EC (GA3) & BC (GA2))*, *z196/z114*, *zEC12*

- **CP Assist for Crypto Function (CPACF)**
  - **DES (56-, 112-, 168-bit), new chaining options**
  - **AES-128, *AES-192, AES-256*, new chaining options**
  - **SHA-1, SHA-256, *SHA-512 (SHA-2)***
  - **PRNG**
  - **Protected Key**



- **Single CPACF per CP on zEC12 & z9**

TechDoc WP100810 – A Synopsis of System z Crypto Hardware

System z Secure Key Crypto Hardware

- **Secure Key DES/TDES (z9)**
- **Secure Key AES (z9)**
- **Financial (PIN) Functions (z9)**
- **Key Generate/Key Management (z9)**
- **Random Number Generate and Generate Long (z9)**
- Protected Key Support (CEX3 on z10)
- **SSL Handshakes (z9), ECDSA support (CEX3 on z196)**
- EP11 (CEX4S)

TechDoc WP100810 – A Synopsis of System z Crypto Hardware

Master Keys

- **ICSF uses five master keys to protect operational keys**
  - DES Master Key (DES-MK aka SYM-MK)

    - 128 bit key / 192 bit key
    - Protects DES/TDES (symmetric) application keys
  - AES Master Key (AES-MK)

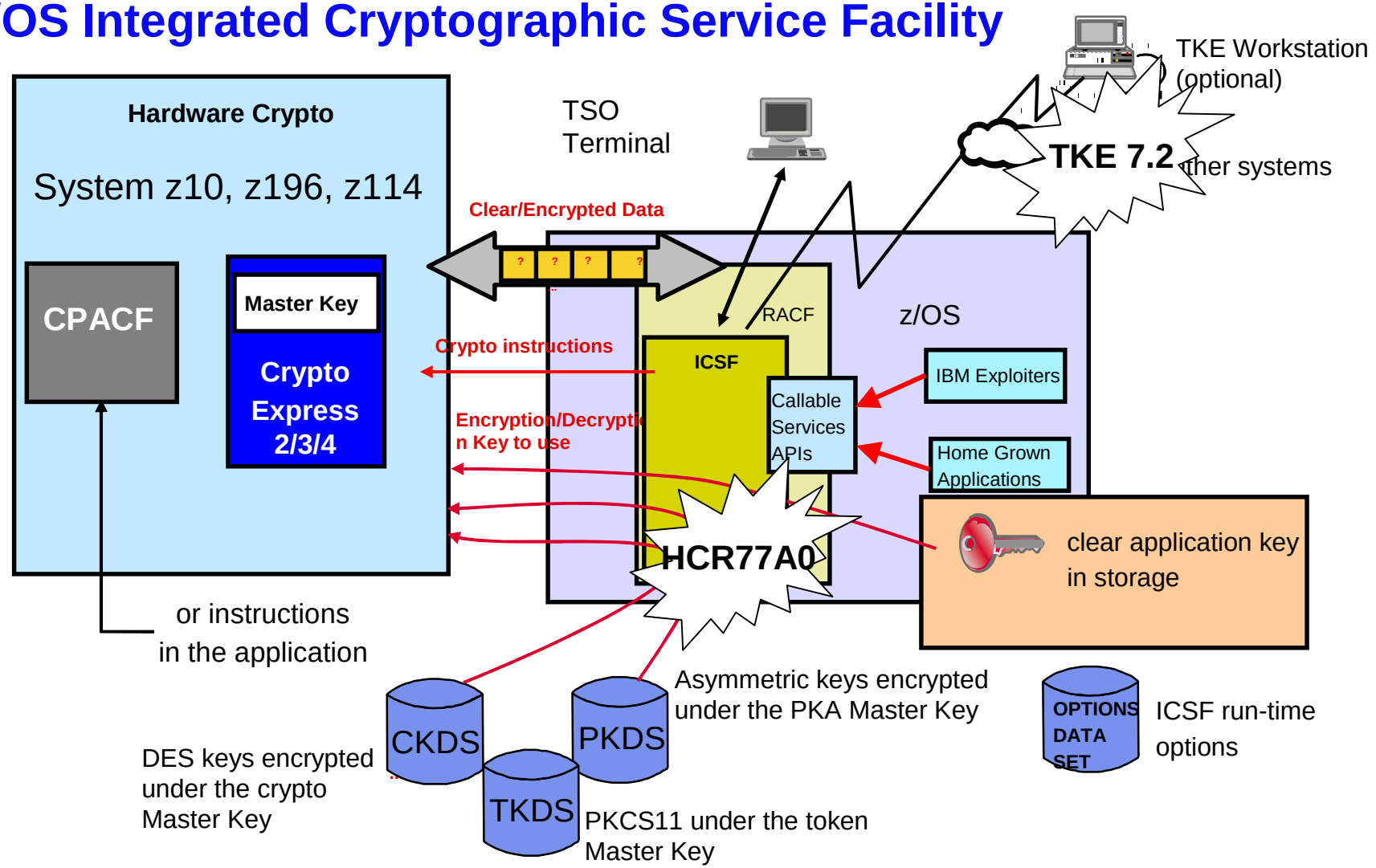
    - 256 bit key
    - Protects AES (symmetric) application keys
  - Asymmetric-keys master key (RSA-MK aka ASYM-MK)

    - 192 bit key
    - Protects RSA (asymmetric) private keys
  - Elliptic Curve Master Key (ECC-MK)

    - 256 bit key
    - Protects ECC (asymmetric) private keys
  - **Enterprise PKCS #11 Master Key (P11-MK)**

    - 256 bit key
    - Protects PKCS #11 keys
- **Stored within the secure hardware boundary of the cryptographic coprocessor**

z/OS Integrated Cryptographic Service Facility

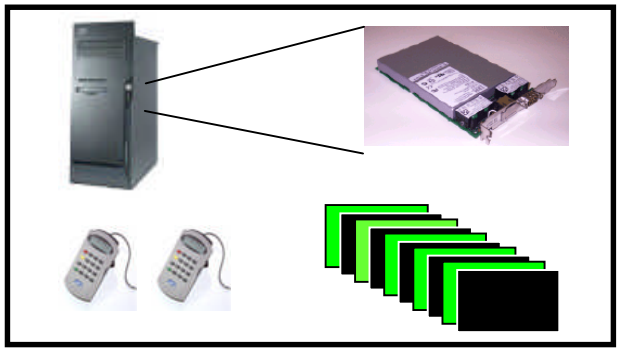


Access to the cryptographic services and keys can be controlled by RACF with the CSFSERV and CSFKEYS classes

Trusted Key Entry (TKE) Workstation

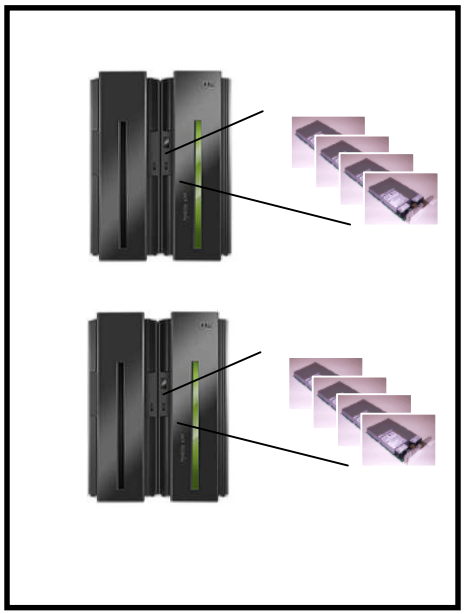
Components

- Workstation with a 4765 Cryptographic Coprocessor
- **TKE 7.2 LIC**
- **Smart card readers and smart cards**
  - Required if using Enterprise PKCS #11 LIC
  - Optional if using IBM CCA LIC



Purpose

- Used to manage multiple Cryptographic Coprocessors and keys on various generations of System z (zEC12, z196, z114 and z10 EC and BC) from a single point of control
  - Support requirements for standards
  - Simplification of tasks



Enhancements

- Support of new hardware or firmware functions
  - Support for Crypto Express4S defined as a CCA coprocessor
  - Required for Crypto Express4S defined as an Enterprise PKCS #11coprocessor
  - New DES operational keys
  - New AES CIPHER key attribute
  - Allow creation of corresponding keys
  - Support 4 smart card readers
- Support requirements for standards
  - Stronger key wrapping

Linux on System z Crypto Stack

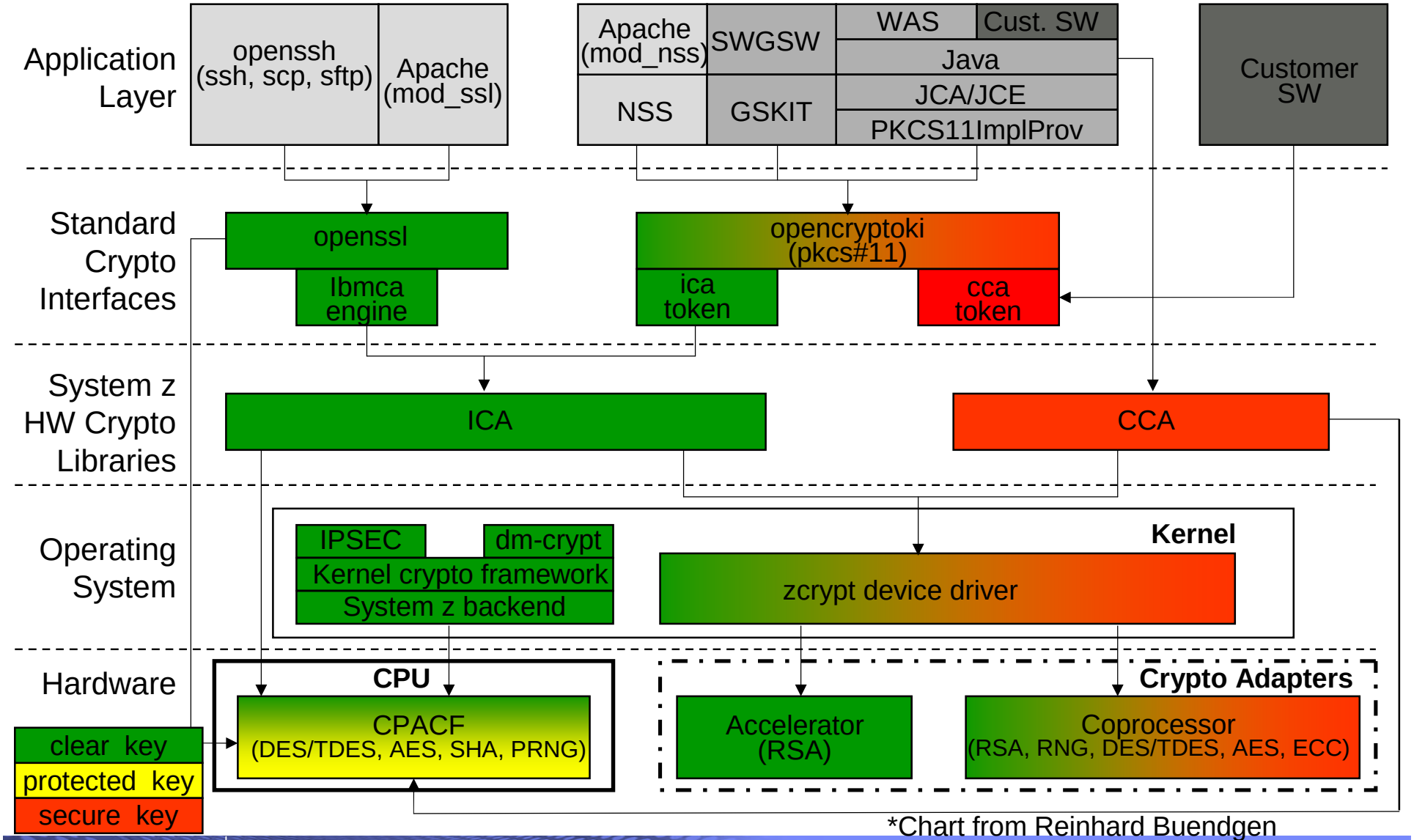
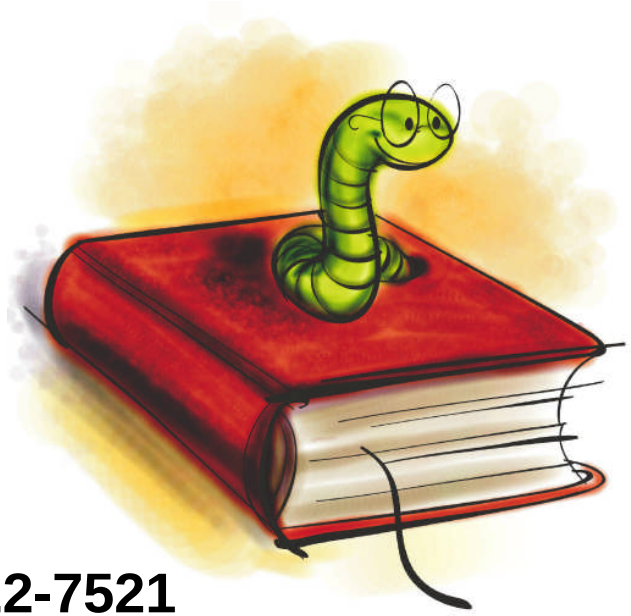


*Chart from Reinhard Buendgen

References

- **Cryptography Books**
  - Bruce Schneier, ‘Applied Cryptography Second Edition: Protocols, Algorithms, and Source Code in “C”’, Addison Wesley Longman, Inc., 1997
  - Simon Singh, ‘The Code Book’, Anchor Books, 1999
  - Niels Ferguson, Bruce Schneier, ‘Practical Cryptography’, Wiley Publishing, Inc. 2003
- **Standards**
  - www.ietf.org – Internet Engineering Task Force
  - www.csrc.nist.gov – Computer Security Resource Center of NIST
  - www.rsasecurity.com/rsalabs - Research site for RSA Security
- **Free Stuff**
  - www.scmagazine.com - SC Magazine
  - www.counterpane.com – Bruce Schneier web site with monthly newsletter

IBM Pubs



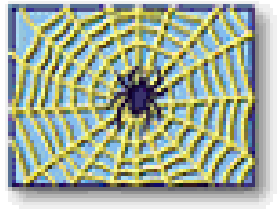
- **ICSF Overview, SA22-7519**
- **ICSF Administrator's Guide, SA22-7521**
- **ICSF Application Programmer's Guide, SA22-7522**
- **ICSF System Programmer's Guide, SA22-7520**

z/OS Web Download Site

http://www.ibm.com/systems/z/os/zos/downloads/

IBM Resources (on the web)

- **Redbooks – www.redbooks.ibm.com 'Crypto'**
  - IBM zEnterprise EC12 Technical Introduction, SG24-8050
  - IBM zEnterprise EC12 Technical Guide, SG24-8049
  - IBM zEnterprise 196 Configuration Setup, SG24-7834
  - IBM zEnterprise System Technical Introduction, SG24-7832
  - IBM zEnterprise 196 Technical Guide, SG24-7833
  - IBM zEnteprise 114 Technical Guide, SG24-7954
  - System z Crypto and TKE Update, SG24-7848



- **ATS TechDocs Web Site www.ibm.com/support/techdocs (Search All Documents for keyword of 'Crypto')**
  - WP100810 – A Synopsis of System z Crypto Hardware
  - WP100647 – A Clear Key/Secure Key/Protected Key Primer

Linux Secure Key Crypto - Information & Download

- Crypto Cards Hardware Overview - http://www.ibm.com/security/cryptocards/
- PCI-E Cryptographic Coprocessor (CEX3) - http://www.ibm.com/security/cryptocards/pciecc/overview.shtml
- Crypto Product Summary – http://www.ibm.com/security/cryptocards/pcixcc/overproduct.shtml
- CCA Overview - http://www.ibm.com/security/cryptocards/pcixcc/overcca.shtml
- PCI-E Cryptograhpic Coprocessor Library - http://www.ibm.com/security/cryptocards/pciecc/library.shtml
- CCA Library Download – http://www.ibm.com/security/cryptocards/pciecc/ordersoftware.shtml
- Cryptographic Coprocessor Order Information - http://www.ibm.com/security/cryptocards/pciecc/order.shtml
- PCI-E Cryptographic Coprocessor Support - http://www.ibm.com/security/cryptocards/pciecc/support.shtml
- Cutting Edge Cryptography by Peter Spera, May/June 2007 IBM Systems Magazine - http://www.ibmsystemsmag.com/mainframe/mayjune07/features/14233p1.aspx

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