A Standards-based Approach to IP Protection for HDLs

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Overview

- Introduction
- A Brief Status
- First Look at The Flow
- Encryption Technology Concepts
- Key Management
- Second Look at the Flow
- Examples of the Protect Directives
- A Few Missing Details
- Recommendations for EDA Tool and IP Providers

IP Protection Goals

- **Deliver HDL-based IP to potential customers you do not completely trust**
- **Fast turnaround from design to delivery**
- **Low cost to protect**

Make money while protecting your investment

Some Approaches to IP Protection

- Brick and Mortar Isolation - the Design Center
- Trusting the Customer - Contractual Protection
- Equivalent Models - an abstraction

They all involve compromise in cost, quality, lead time, or effectiveness!

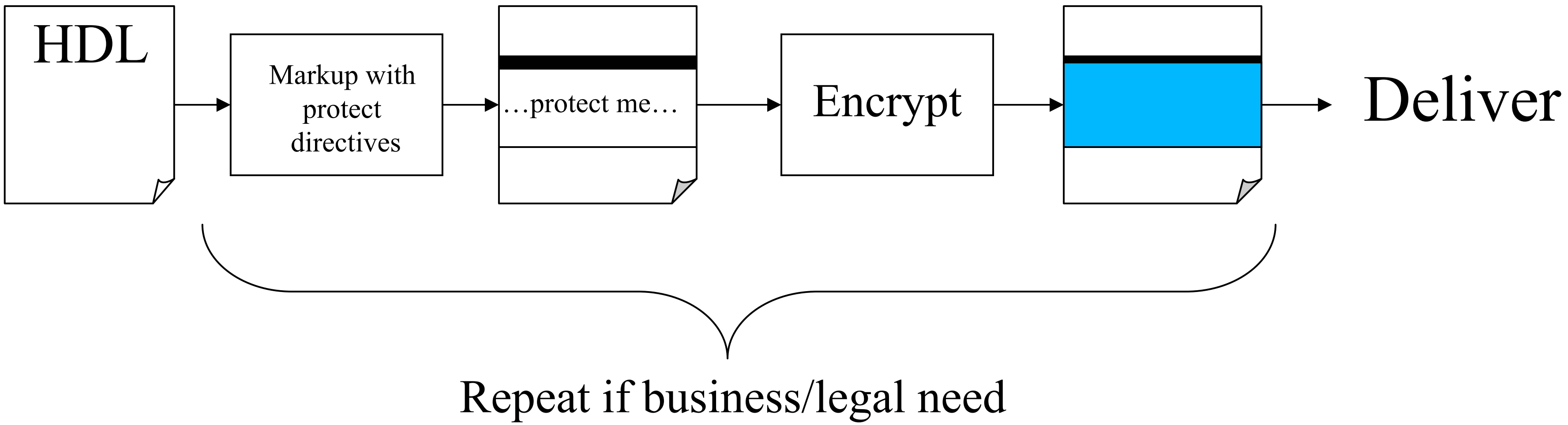
- Encryption – a lossless transformation rendering IP unreadable

  Caution: poor implementation could give false hope

Verilog And VHDL Have Developed A Standard For IP Protection

- **Based on well-known standardized methods for strong encryption, encoding, and authentication**
- **Markup of unprotected HDL source at the token level**
- **Flexibility to meet issues outside the standards, e.g., international legal considerations**
- **IEEE Verilog 1364 - 2005**
- **Accellera VHDL 2006 - pending approval 7/2006**
- **Minor differences reflect normal syntax considerations and learning curve**

Steady-State Flow At IP Vendor

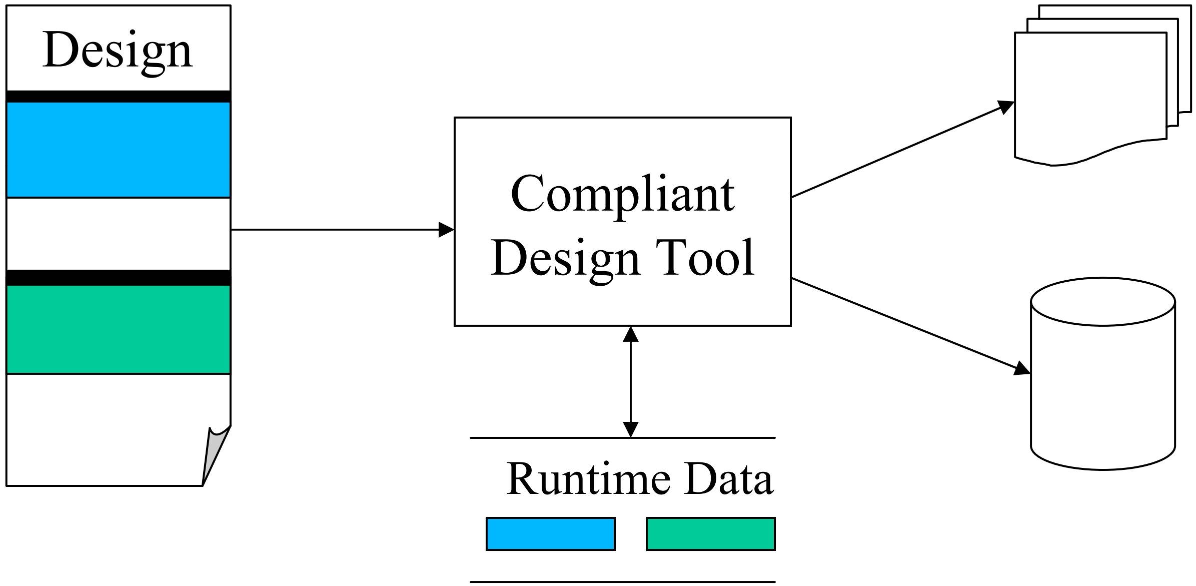


The Steady-State Flow At IP Vendor

- Develop your HDL model
- Markup sections of the model with encryption directives
  - optionally sanitize source, obsfucate it, etc.
- Encrypt the model once
  - with any standards-compliant encryption tool
- Deliver the IP to your customers
  - directly, in a design kit, via a 3rd party, …

Repeat last 3 steps if legal/business considerations dictate different encryption methodology

The Customer Experience



- **Customer works in his shop**
- **IP is only decrypted within the tool and just for its intended purpose**
- **The tool is obligated not to reveal information that would compromise protected IP**
- **The encrypted IP is otherwise virtually impossible to crack (OK, we don't know what the NSA can do :)**

Symmetric Cipher

- A secret key is used to convert plaintext to ciphertext
- The ciphertext can be sent over an insecure channel without concern of compromise
- The same secret key must used to decrypt ciphertext back into plaintext
- The secret key is delivered in some out of band communication
- Secure bi-directional exchange of messages
- Symmetric ciphers may be implemented in hardware or software and are generally quite fast

Asymmetric Cipher

- **A pair of keys - one to encrypt, the other to decrypt**
- **One key is designated the public key, the other the private key**
- **Solves key delivery over an insecure channel**
- **Secure way of delivering messages in one direction**
- **Very versatile mechanism applied many different ways**
- **Much slower decryption performance**

…commonly 1000x slower!

Asymmetric Cipher

- To send information only you can read, I'll need your public key
- Guarantee is anything I send to you can only be read by you (…if that's really your public key)
- Anyone else can send you private communication using your public key, too
- You may need to authenticate that this came from me
- Eavesdropping doesn't hurt much, but "man in the middle" could

Digital Envelopes

- A hybrid approach employing enhanced key security of asymmetric ciphers with the performance of symmetric ciphers
- The data (your IP) is encrypted with a session key using a symmetric cipher
  - One use key, generated in a cryptographically random way
- The session key is placed in a secure digital envelope
  - i.e., encrypted with the public key of an asymmetric cipher
- The ciphertext and the secure envelope are delivered to the user
- The EDA tool decrypts the envelope, gets the session key, and then decrypts the data
- You can send many envelopes holding the same session key at the same time with your data

Digital Signatures

- **A signature identifies you**
  - **Legal significance, weakly resistant to forgery**
- **In a digital signature, I take a little bit of information about me and/or my message**
- **To sign, I encrypt it with my *private* key (asymmetric cipher is *not* about which key is revealed)**
- **With my public key, anyone can authoritatively determine that I signed it**
- **Two important applications to discuss**
  - **Managing keys**
  - **Authenticating delivered IP**

Public Key Certificates Build Trust

- **A public key and information about its owner that a trusted party digitally signs is called a *<u>public key certificate</u>***
- **The trusted party, the certification authority (CA), guarantees that this is really that owner's public key**
- **The certificate is like a passport and the CA is like your government state department (or notary public)**
- **The CA can be an external service provider, an industry or government agency**
  - **ITU X.509 public key infrastructure standard**
- **The signer is trusted by you and supports you in trusting someone else**
- **Trust may be built organically using the "*<u>web of trust</u>*" model**
  - **(open pgp, key signing parties, key servers..)**

Using Signatures for Authentication

- Compute a fixed length binary string from an arbitrarily long message, its ***message digest***
- Cryptographic hash function insures that no 2 messages will have the same digest
- Decrypt a message, compute its digest, decrypt the signed digest, and compare
- This process validates the authenticity of the message
- Using message digests is an option in the standard

Sanity Check

- Strong encryption is possible with both symmetric and asymmetric ciphers
  - Brute force attacks are computationally infeasible
- Information is secure unless you have the keys
- Key attacks could eavesdrop on key transmission, intercept the key and deliver a fake key, or steal the keys
- Seems it's all about managing the keys
- Which I claim is about establishing a web of trust and using good quality tools

The Key Management Problem

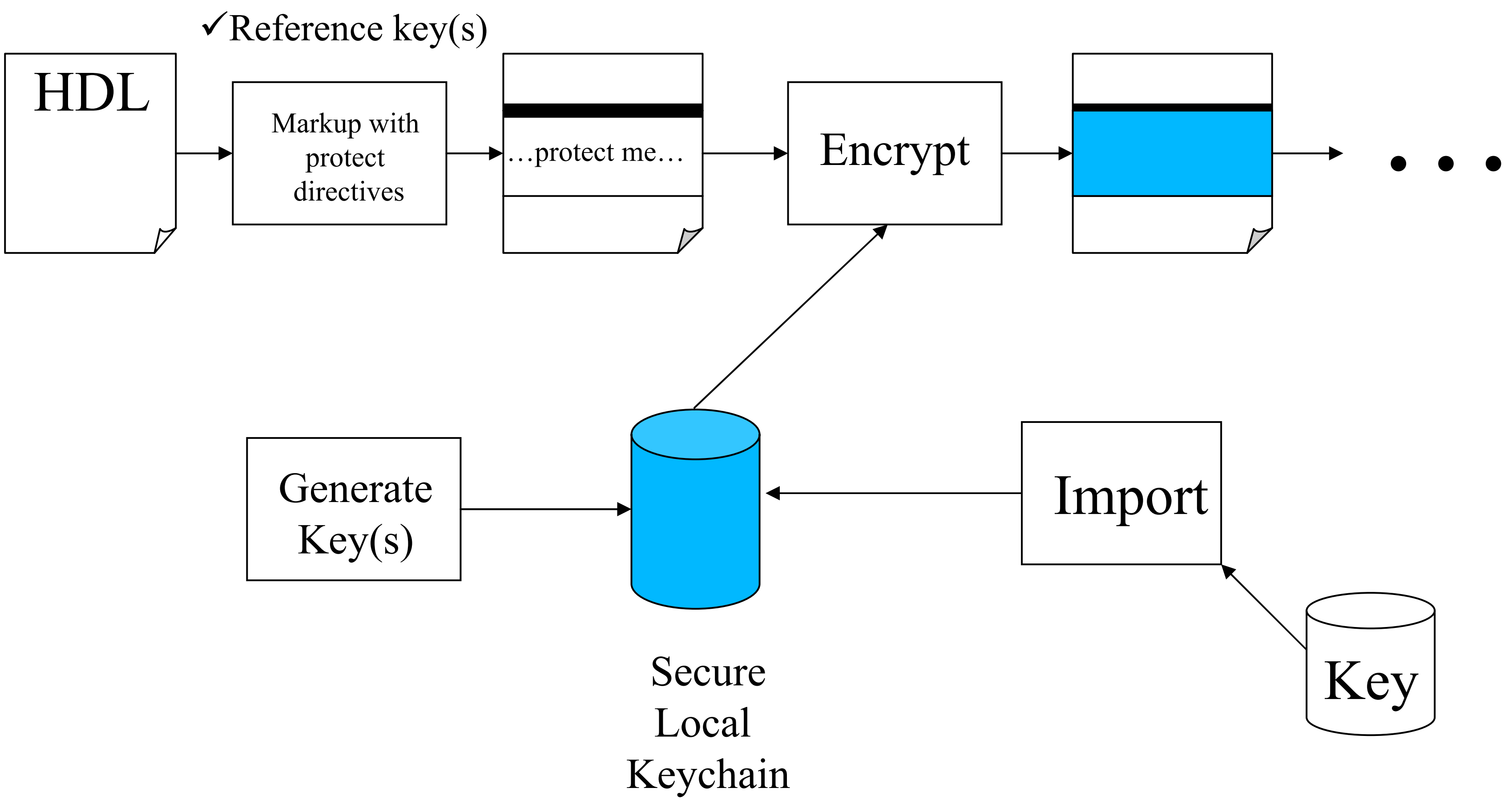
- The HDL standards do not say how users and tools manage keys
- You, as the IP provider, may have numerous keys
  - 1 per tool vendor, tool, tool rev, user…
  - 1 per model, per model revision, etc.
- You manage these keys inhouse and delivers some of them
- Tool Vendor has the same problems and one more
  - potentially many keys from many IP providers
  - tools must be delivered to customers with secured set of keys available

What does it take to make this manageable?

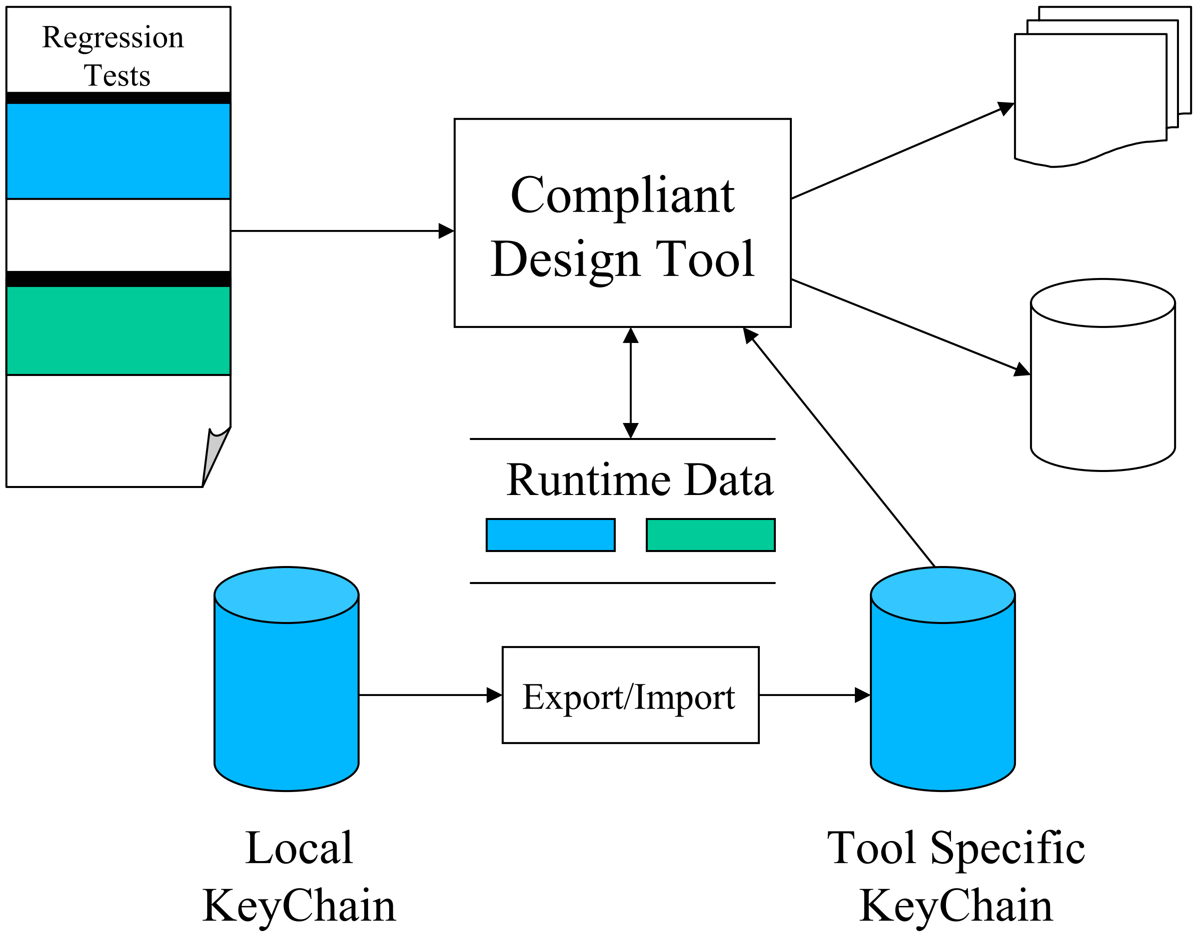
The Secure Keychain Concept

- In the standard, keys are identified by the tuple of owner and name
- Secure keychain is an encrypted persistent database that accesses a key by its identifiers
- Ability to import, remove, and export keys (maybe some other housekeeping utilities)
- Only the keychain manager enabled tools can access the database
- The concept has a role as a standalone program, part of encryption tool suite, and part of a compliant EDA design tool

A Second Look at the Flow For Producing Protected IP



Validate Design Tool



Validate EDA Design Tool

- ***If necessary***, export keys from your local keychain and import them into a design tool specific local keychain
- Qualify the customer experience with your IP
  - Run validation tests on models using your protected IP with that design tool
- Qualify the tool
  - Inspect all tool outputs for exposure of IP, look at runtime environment for implementation weakness
- Deliver local keychain securely to vendor for hardening into a tool release(its default keychain)
- Option to deliver a tool specific keychain with IP to directly customer?
  - Depends on the strength of protection of the local keychain

Choose Wisely

- The secure keychain is just a concept to discuss principles
- As an IP Provider, to give keys to my vendors I might:
  - generate a key in a file, zip it, and email it…bad idea that often works
  - write it to a memory stick and Fedex it or hand carry it…better
  - Use PKI or web of trust to establish secure communications
- As a tool provider handling my customers keys I might:
  - Allows a tester to copy it to a work directory that anyone can read
  - Write it to a open file that is shipped in "customer_keys" directory
  - Use best practices for handling secured communications and deliver with secure keychain
- The standard has sound mechanisms, but anything can be defeated by careless actions and weak implementation

Simple Secret Key IP Protection Scenario

```
`protect data_keyowner="ACME IP Provider",
   data_method="aes192-cbc"
`protect begin
IP source text ...
`protect end
```

Simple Secret Key IP Protection Scenario

```
`protect begin_protected
`protect
  encrypt_agent="Encryptomatic",encrypt_agent_in
  fo="2.3.4a"
`protect data_keyowner="ACME IP Provider",
  data_method="aes192-cbc"
`protect encoding = (enctype="base64",
  line_length=40, bytes=4006), data_block
```

encoded encrypted IP …

```
`protect end_protected
```

Default IP Protection Scenario

`protect begin

IP source text ...

`protect end

- **encryption tool selected key and algorithm**
- **can only be decrypted by related tools that share key knowledge**
- **no user generation or exchange of keys, no referencing of them**
- **Interoperable EDA tool suites would use same defaults**
- **Hmm…tool might enable the CAD group to configure defaults**

Default IP Protection Scenario

`protect begin_protected

`protect encrypt_agent="Encryptomatic", encrypt_agent_info="2.3.4a" `protect data_keyowner="Electrowizz Tool Co", data_keyname="crypto-101", data_method="des-cbc"

`protect encoding = (enctype="base64", line_length=40, bytes=4006), data_block *encoded encrypted IP …*

`protect end_protected

Digital Envelope Protection Scenario

```
`protect key_keyowner="ACME IP Owner",
   key_name=”For Joe Designer”,key_method="rsa",
   key_block
`protect data_method="aes192-cbc"
`protect begin
IP source text ...
`protect end
```

- Key_* directives indicate digital envelope

Digital Envelope Protection Scenario

`protect begin_protected

`protect encrypt_agent="Encryptomatic", encrypt_agent_info="2.3.4a"

`protect key_keyowner="ACME IP Owner", key_name=”For Joe Designer”,key_method="rsa"

`protect encoding = (enctype="base64", line_length=40, bytes=256), key_block

encoded encrypted session key ...

`protect data_method="aes192-cbc"

`protect encoding = (enctype="base64", line_length=40, bytes=4006), data_block

encoded encrypted IP ...

`protect end_protected

Multiple Envelopes

```
`protect key_keyowner="ACME IP User1",
    key_method="rsa", key_block
`protect key_keyowner="ACME IP User2",
    key_method="elgamal", key_block
`protect key_keyowner="ACME IP User3",
    key_method="aes192-cbc", key_block
 `protect data_method="aes192-cbc"
 `protect begin
IP source text ...
`protect end
```

A Signed Digital Envelope

```
`protect key_keyowner="ACME IP User",
   key_method="rsa", key_block
`protect data_method="aes192-cbc"
 `protect digest_keyowner="ACME IP Author",
   digest_key_method="rsa"
 `protect digest_method="sha1", digest_block
`protect begin
IP source text ...
`protect end
```

Other Protect Directives in the Standard

- Viewports
  - Opens an aspect of your opaque IP for usability
  - Immature aspect of the standard
- Licensing
  - Require a license check to access IP
  - Provisioned with marginal security
- Encoding
  - Choose method of encoding binary ciphertext for textual representation
- Documentation
  - Comments and/or automatic annotation by encryption tools

Standard Details

- DES is the only required cipher method
  - Symmetric algorithm and highly exportable
  - It can be broken by brute force
- SHA-1 and MD5 are only required cryptographic hash functions for computing message digests
  - They are considered to be very good; SHA-1 is the better one
  - Both have been broken, but spoofing IP is not a practical vulnerability
- Provision is made in the syntax for virtually all known and important ciphers, cryptographic hash functions, and encoders

High Quality EDA Tools for IP Protection Should…

- Implement the standard
- Provide additional market-driven ciphers, cryptographic hash functions, encoders
- Provide utilities for key generation, keychain management, and encryption
- Employ best practices for developing encryption tools
- Deploy tools within the applicable law
- Provide a process for establishing secure communication with IP providers
- Collaborate on developing best practice for IP protection

Recommendations

- Advocate your requirements to the EDA vendor community
- Learn how vendors will safeguard your keys in their house and in the field when the tools are in use
- Qualify tools – tool-specific defaults, interoperability, performance, direct attack, runtime information compromise
- Use good counsel on export laws, use of encryption, etc.
- Make sure compromise doesn't originate in your house
- …and you'll make more money with your HDL-based IP!

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Backup Material

- Tremendous amount of info on the web
  - Cryptographic technology
  - Related export law
- Experiment with Open PGP standard tools
  - FSF's GnuPG is a good choice
  - No export restrictions on it to my knowledge (except known sponsors of terror)

Symmetric Cipher

- **DES is a NIST standard, a 64 bit block cipher, with 56 bit key**
- **A workhorse with no known structural attacks, brute force methods have cracked in ~22 hours (~30 2.2GHz Opteron years over 5 months was known level of effort at one time)**
- **It is exportable to non-terrorist countries (but you want a legal opinion, not mine!)**
- **Interim improvement is triple-DES (which is 3 times slower)**

Symmetric Cipher

- AES is the new published NIST standard based on 128 bit blocks and 128, 256, or 512 bit keys
- It was selected from a large field of candidates in a competitive process
- It is unlikely to be cracked in our lifetime

Asymmetric Cipher

- **RSA is most commonly used**
- **Keys of >1024 bits are quite secure, 2048 should give security for decades**