

TPM Laboratory I

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What's this?


```
00 C4 00 00 01 3A 00 00 00 00 00 00 00 01 00 03 00 01 00
00 00 0C 00 00 08 00 00 00 00 02 00 00 00 00 00 00 01 00
DC FC C6 46 3A 97 F0 D9 F2 AB AA 90 82 C6 CC 09 00 50 3F
76 8E FD 07 03 02 0E 6F 08 D1 5E 47 38 2C 20 86 B1 62 1F
4A 81 08 1B 54 83 BD 21 E8 45 4F 58 60 50 CF 5F 88 15 07
0B E1 6C A0 A4 50 5A 53 08 33 A6 D0 B4 05 0B 0B AD 69 36
1E 24 10 91 ED DE A0 BC 97 5B D5 7E A2 BD DA 0F B6 6C D4
53 6F 77 18 4F 2C B6 36 8D 31 89 B3 92 76 69 DF 58 5D 13
2F 09 53 58 A2 57 B7 63 25 D2 F1 9B 9D E5 65 EB 73 70 CE
FF 79 0D 89 86 B7 DB 4D 5A 50 AC AC 4E 3C 86 80 8E C0 D0
81 EA 60 5E BB A4 37 B7 E1 AB 79 46 A0 E4 03 CD 69 40 94
13 84 5C 6A A6 A6 09 D9 1B 3D 90 4E 66 5D 5B E6 53 4E 57
92 32 42 2C 45 37 F5 FC 19 7B 7D 45 49 07 F8 51 56 97 57
5D 9B EC F7 8C 14 A6 AF BF 0B B9 7D D8 89 62 65 45 89 99
A8 67 C9 37 47 49 E8 A6 DA 66 F5 00 FD ED 6D 43 69 94 AD
33 C8 B3 E6 16 86 38 14 DB 23 BA 2E E8 E4 32 1D FF BE 88
E4 76 6C 1C C9 5E C0 E3 C9 64
```


Content

- Introduction to TPMs
- Platform Integration
- Using the TPM with Linux
- TPM commands
- The Chain of Trust

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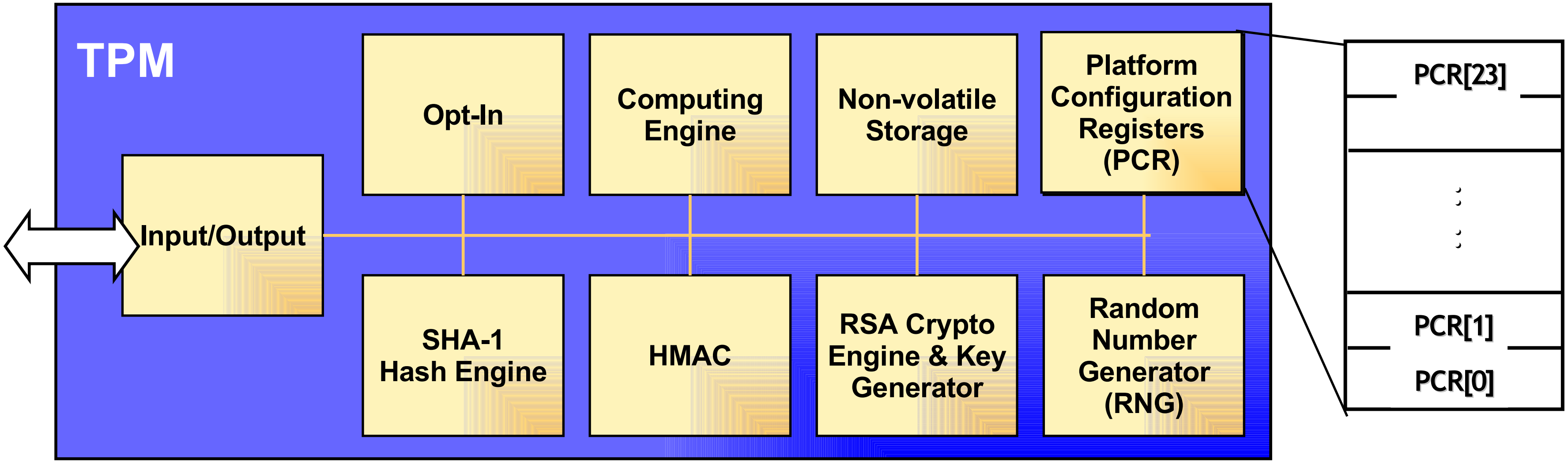
Introduction to TPMs (1)

- Hardware-based random number generators
- Cryptographic functions
  - Signatures, Hash (SHA-1), Encryption (RSA), Key generation
- Platform Configuration Registers (PCR)
  - Storage of integrity measurements



Introduction to TPMs (2)

- TPMs main goals
  - Security Anchor inside the system
  - Sealing / Binding to a certain Platform configuration
  - Attestation of the platform state
- Every TPM has a unique key called **Endorsement Key**
- The TPM has 8 states:

Modes of Operation:

S1 – Enabled – Active – Owned
S2 – Disabled – Active – Owned
S3 – Enabled – Inactive – Owned
S4 – Disabled – Inactive – Owned
S5 – Enabled – Active – Unowned
S6 – Disabled – Active – Unowned
S7 – Enabled – Inactive – Unowned
S8 – Disabled – Inactive - Unowned

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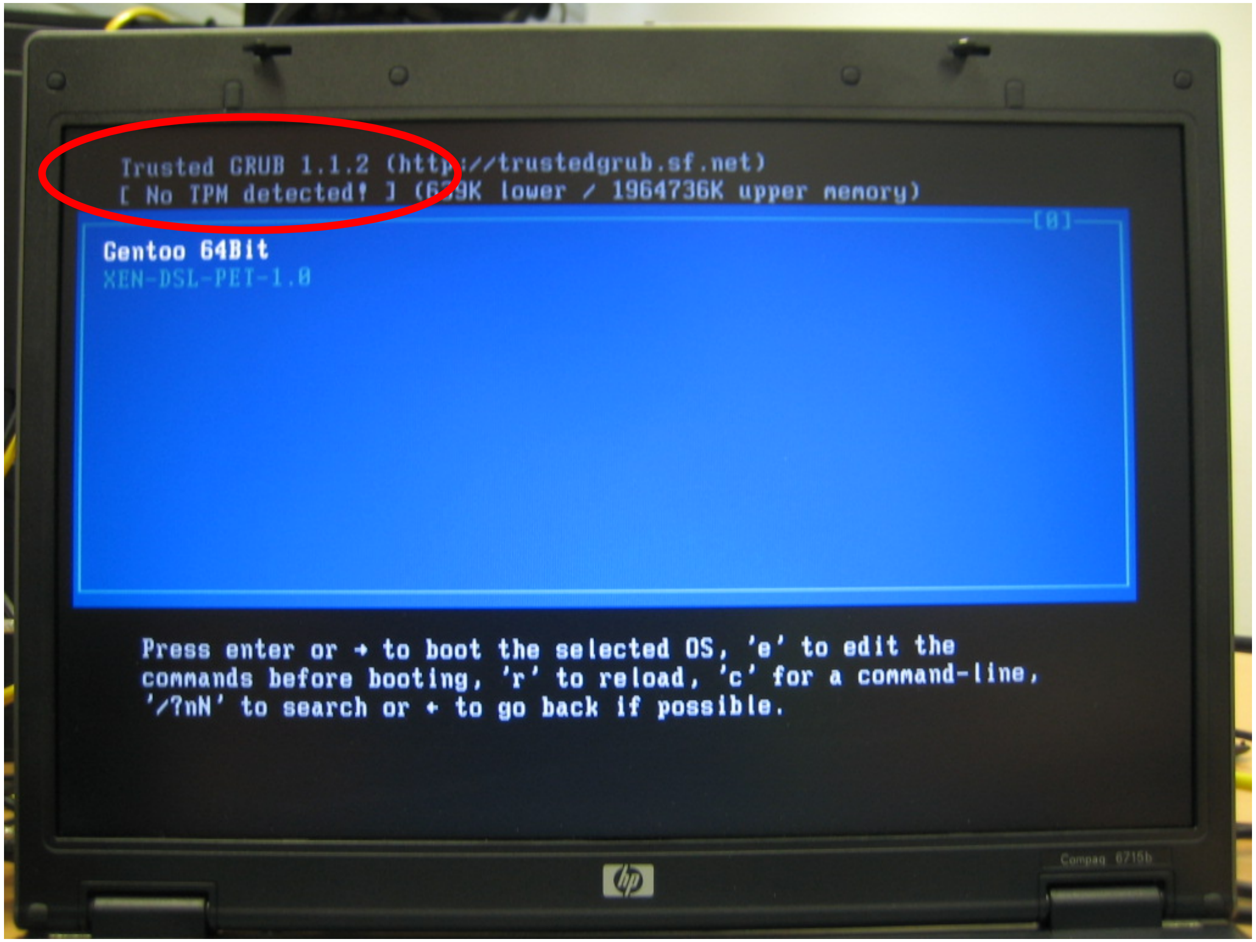
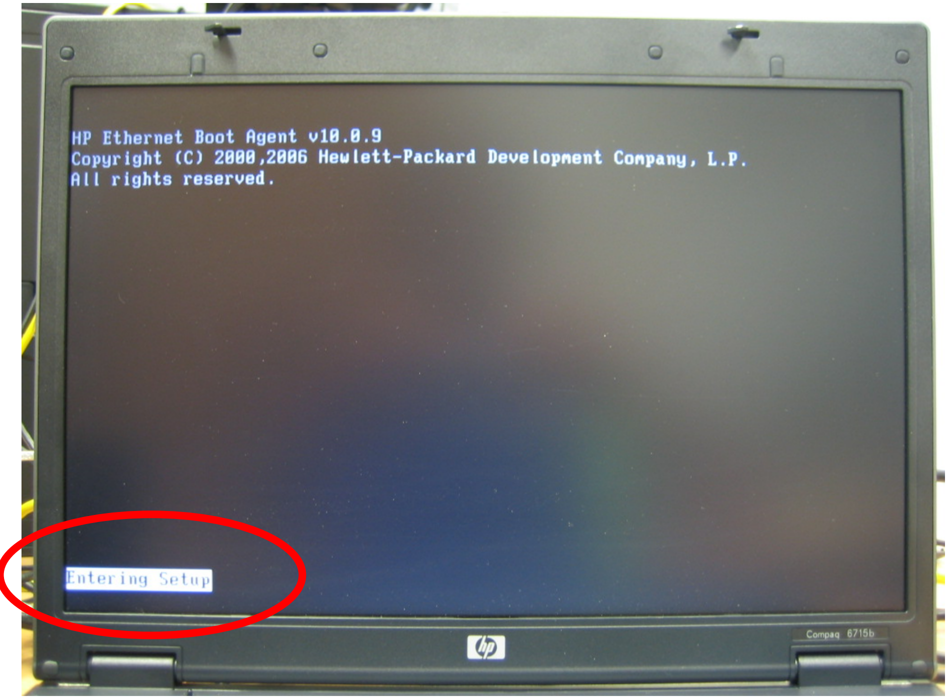
Platform Integration (1)

- TPMs are disabled by default



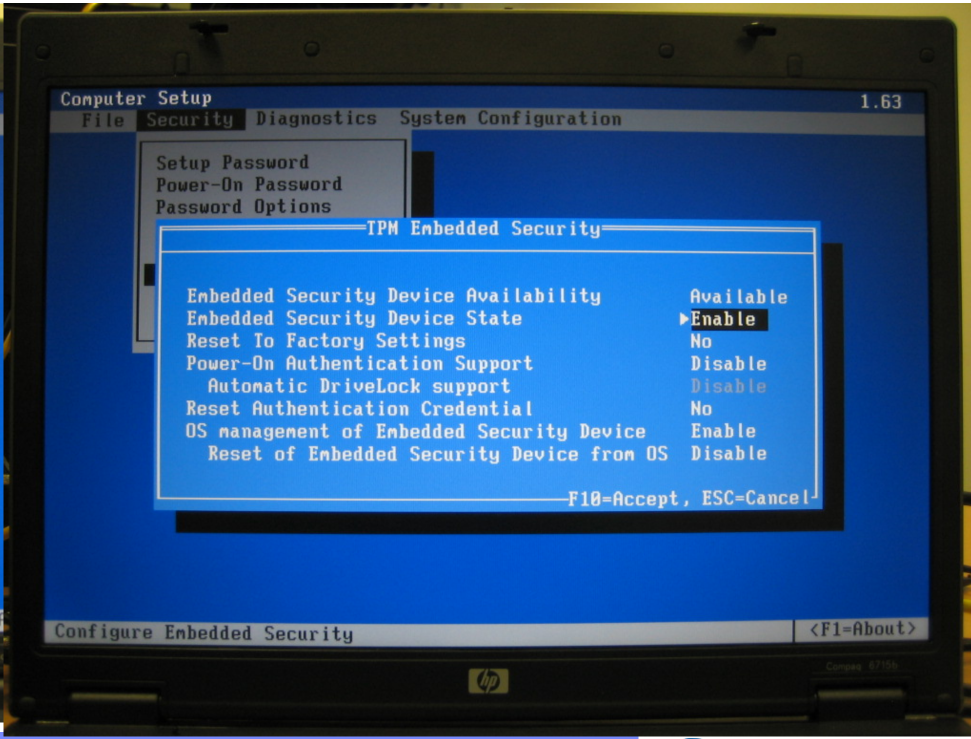
Platform Integration (2)

- Enable the TPM in the BIOS
  - Press F10 to enter BIOS
  - Enter “tpm” as Setup Password



Platform Integration (3)

- Enable the TPM in the BIOS
  - Security -> TPM Embedded Security
  - Embedded Security Device State -> „Enable"



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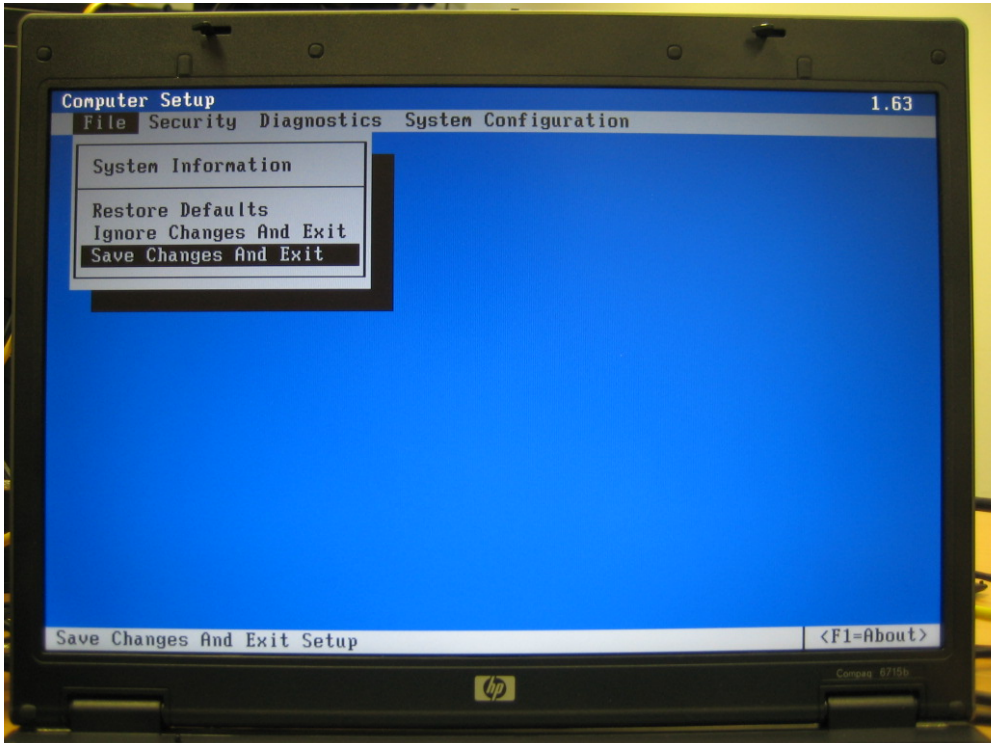
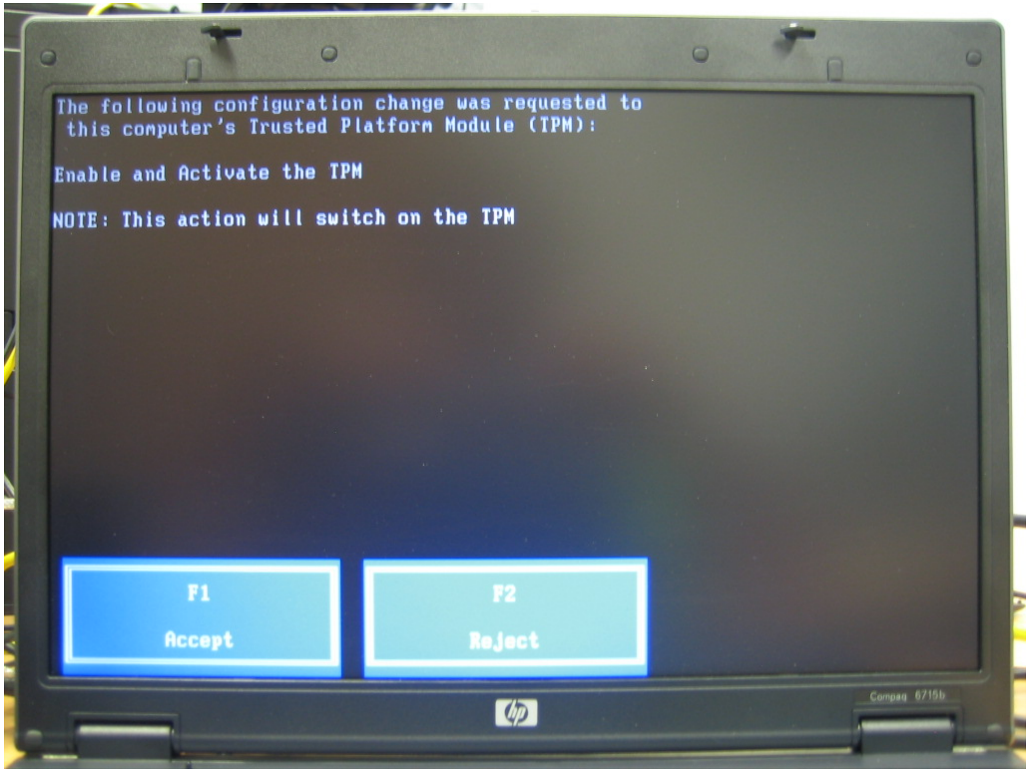
Platform Integration (4)

- Enable the TPM in the BIOS
  - „Save Changes And Exit”



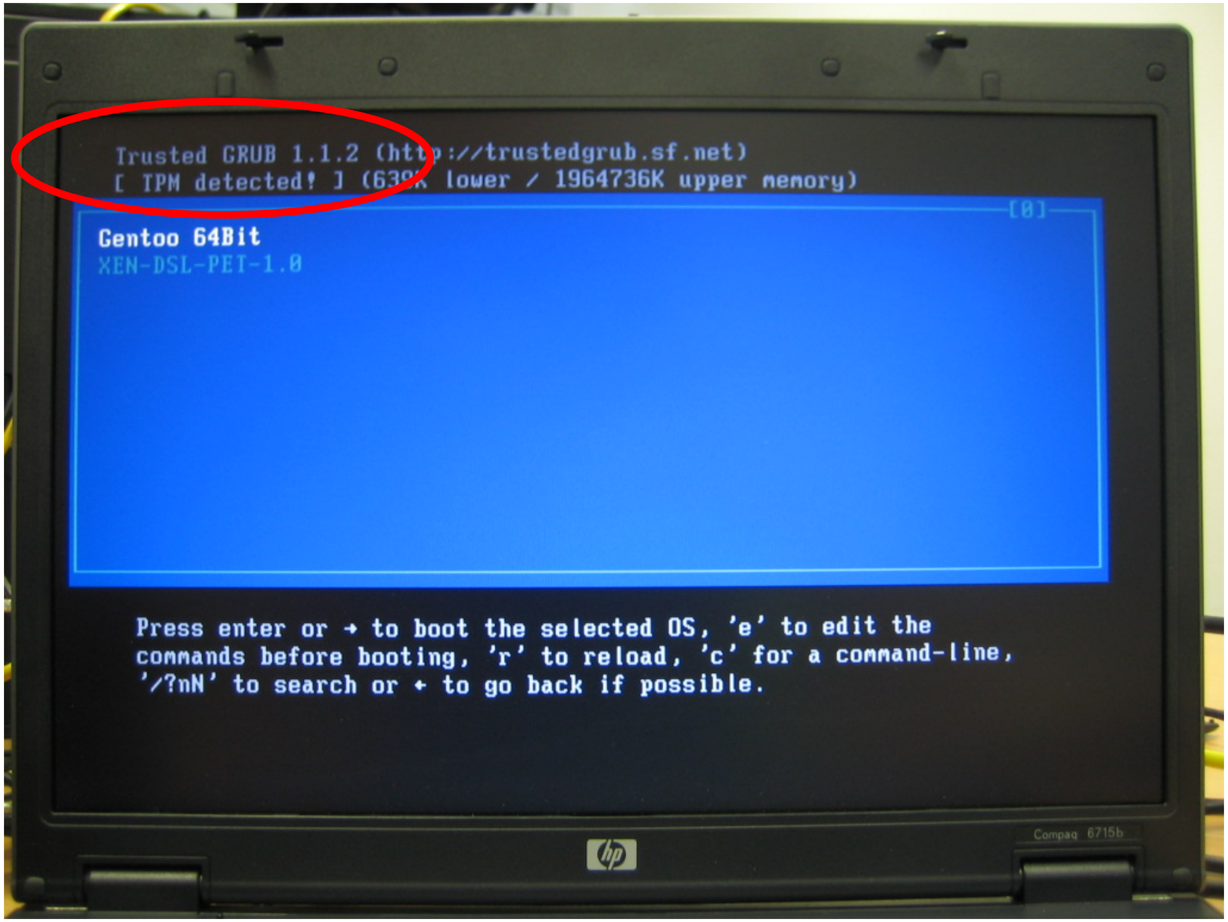
Platform Integration (5)

- Enable the TPM in the BIOS
  - Press “F1” to Accept



Platform Integration (6)

- Now the TPM should be available and detected!



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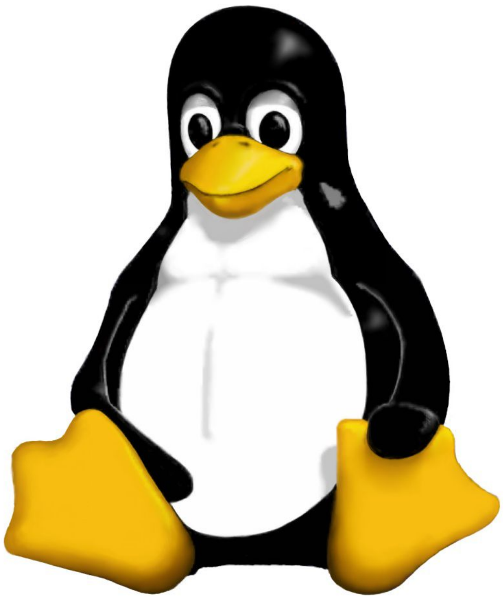
- Using the TPM with Linux
  - TPM device drivers
  - TPM open source software
    - TrouSerS
    - Taking Ownership with TPM-Manager
- TPM commands
- The Chain of Trust

TPM device drivers (1)

- In order to use a TPM with Linux, a TPM device driver has to be available
- Currently, the following device drivers are available within any modern Linux kernel:
  - Atmel TPM 1.1b
    - `modprobe tpm_atmel`
  - NSC TPM 1.1b
    - `modprobe tpm_nsc`
  - Infineon TPM 1.1b + TPM 1.2
    - `modprobe tpm_infineon`
  - Generic TIS driver for TPMs 1.2
    - `modprobe tpm_tis`



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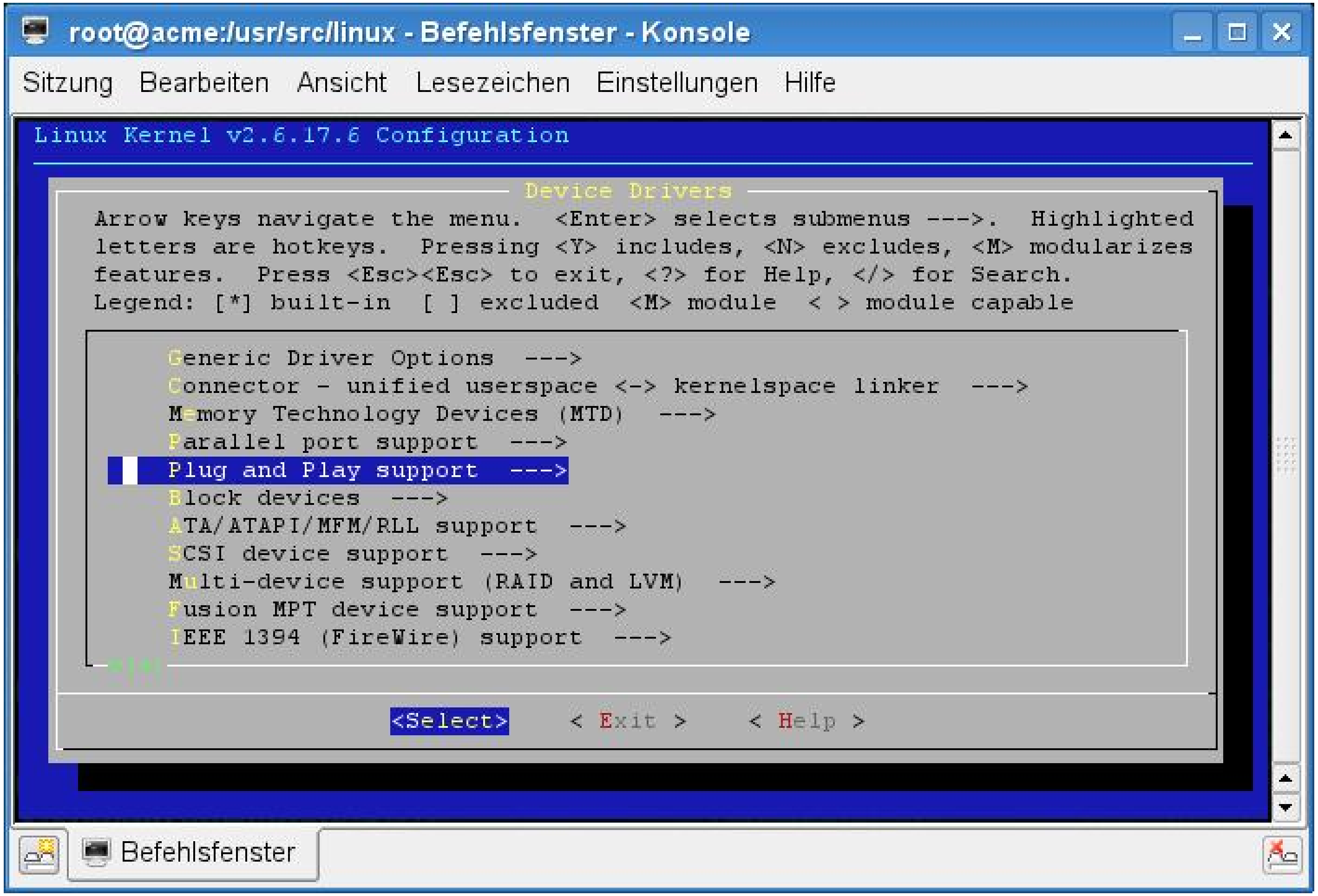
TPM device drivers (2)



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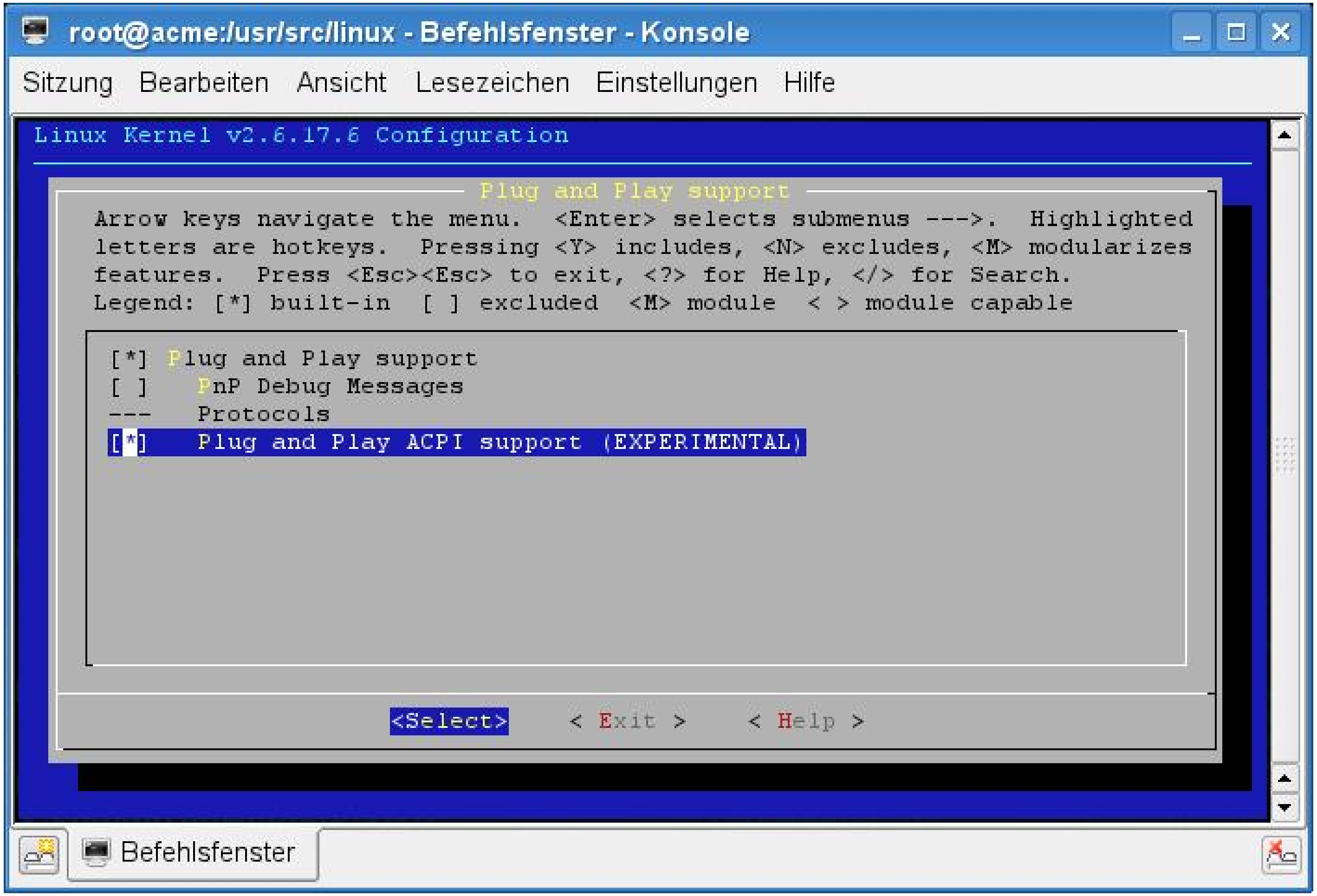
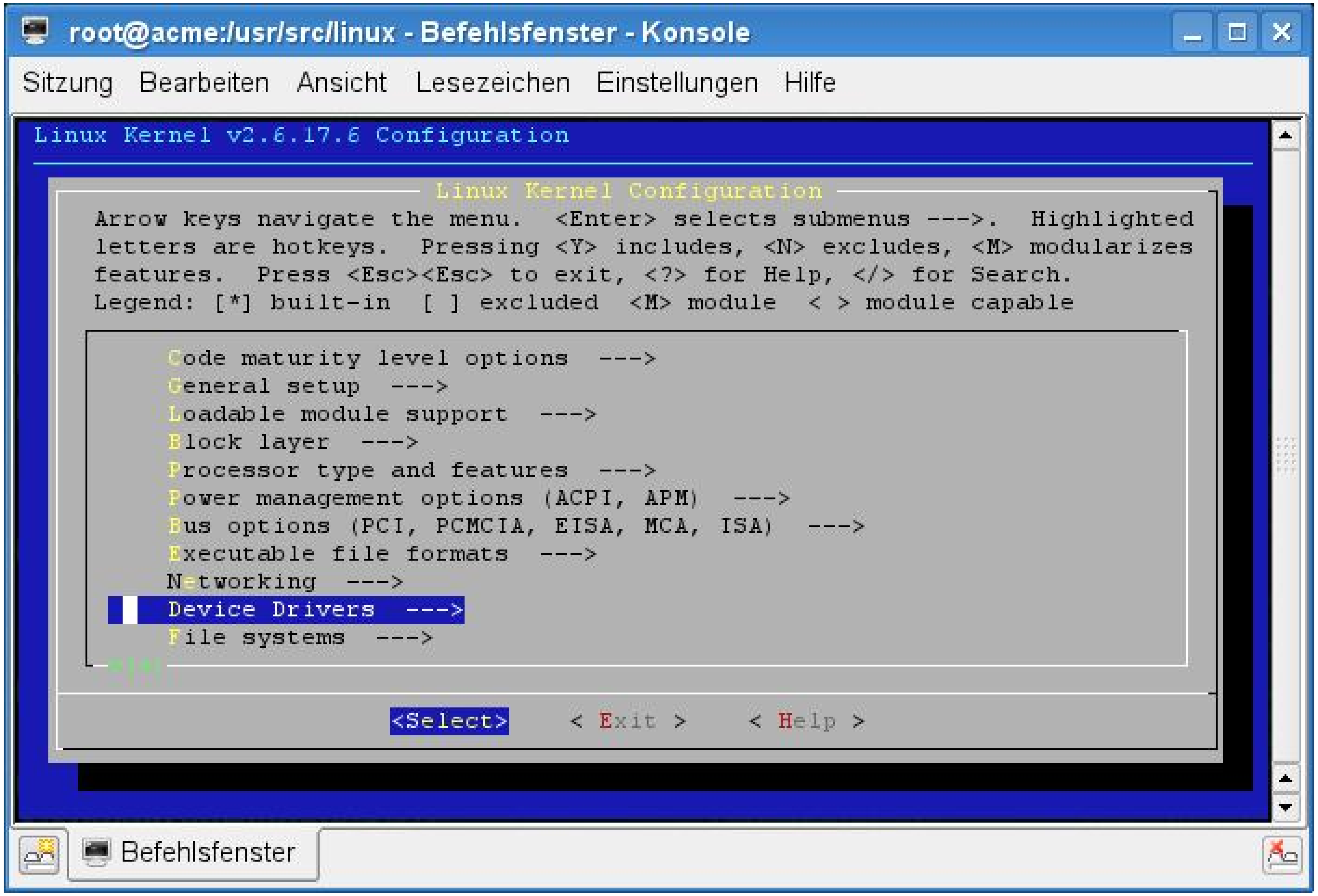
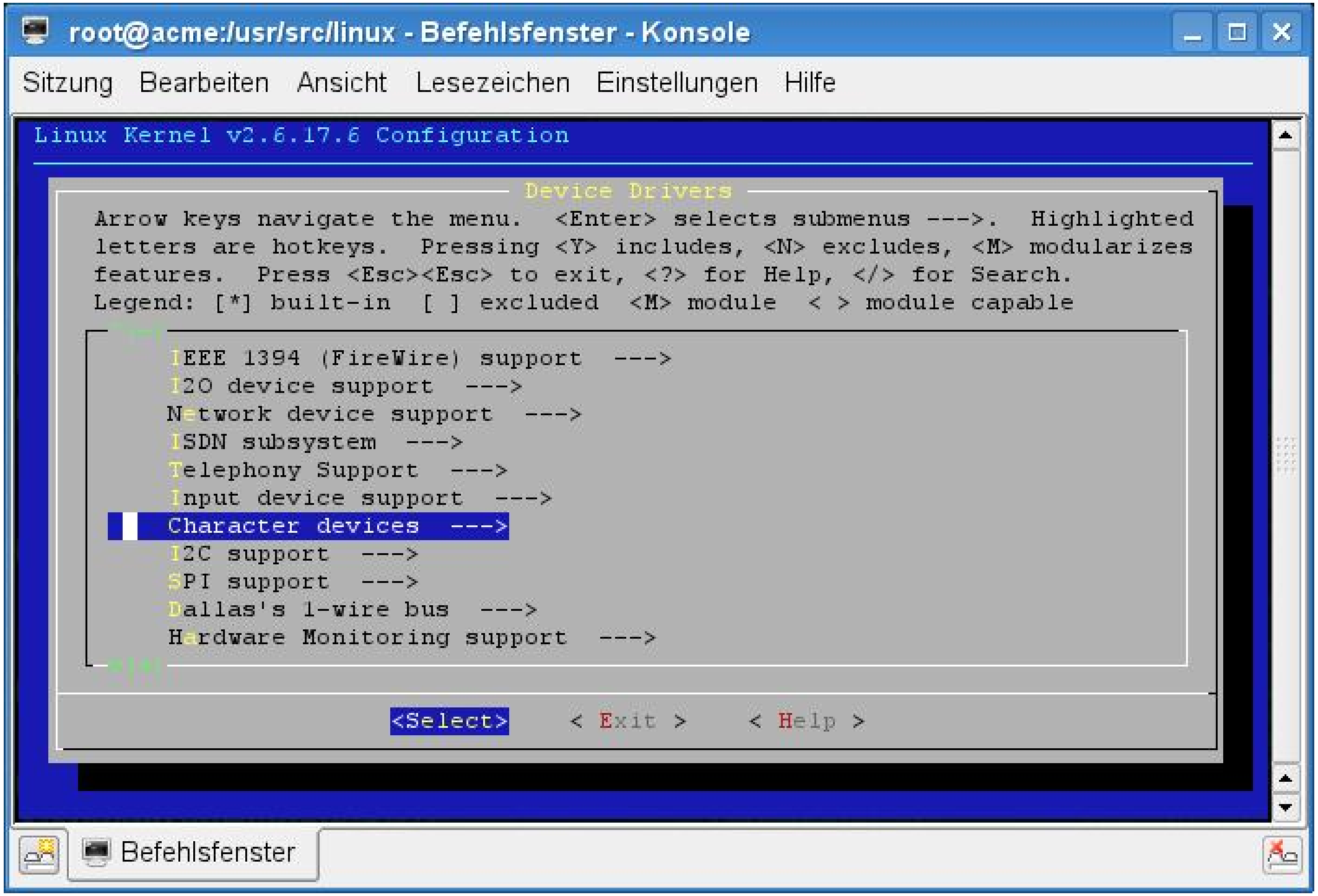
TPM device drivers (3)



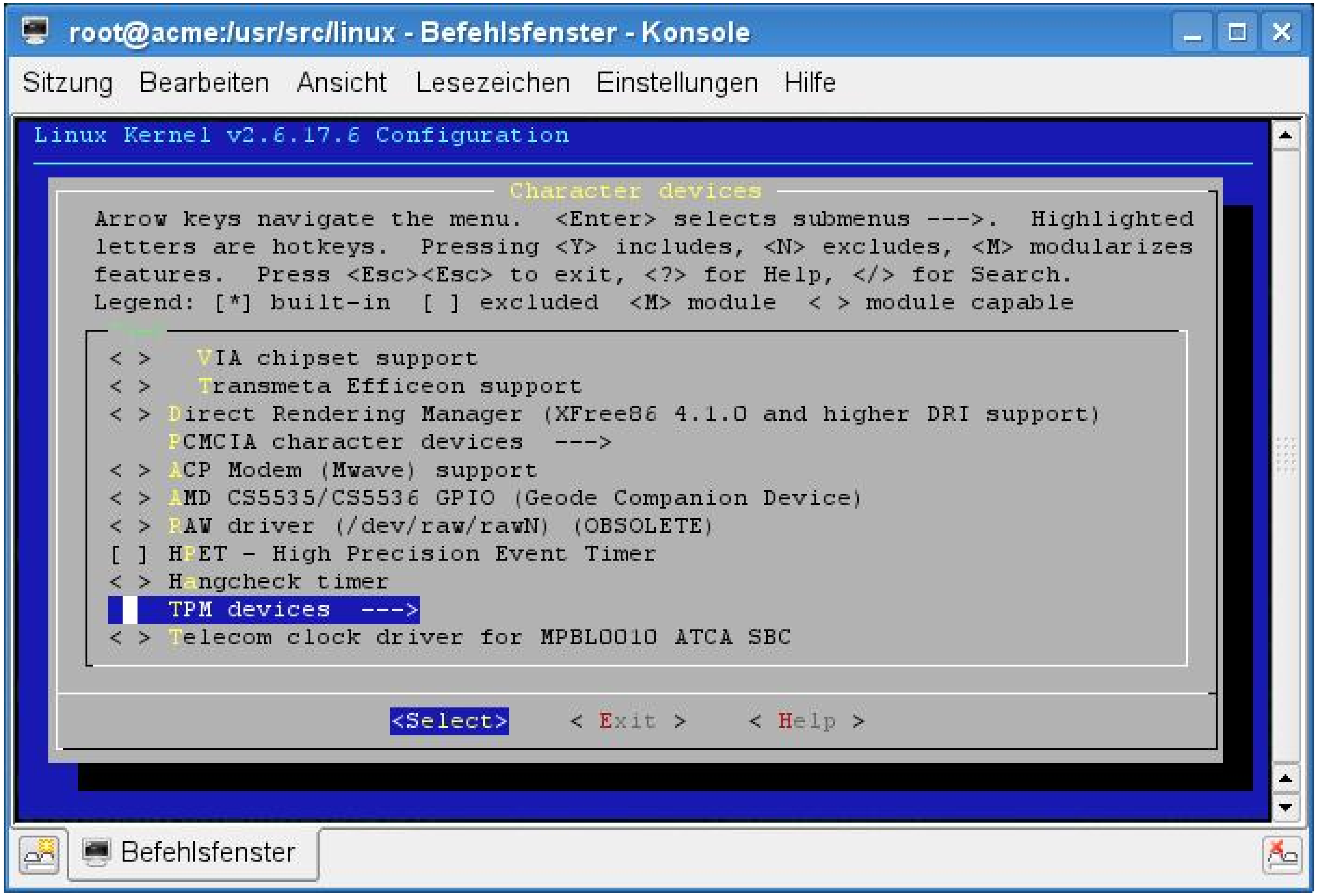
TPM device drivers (4)



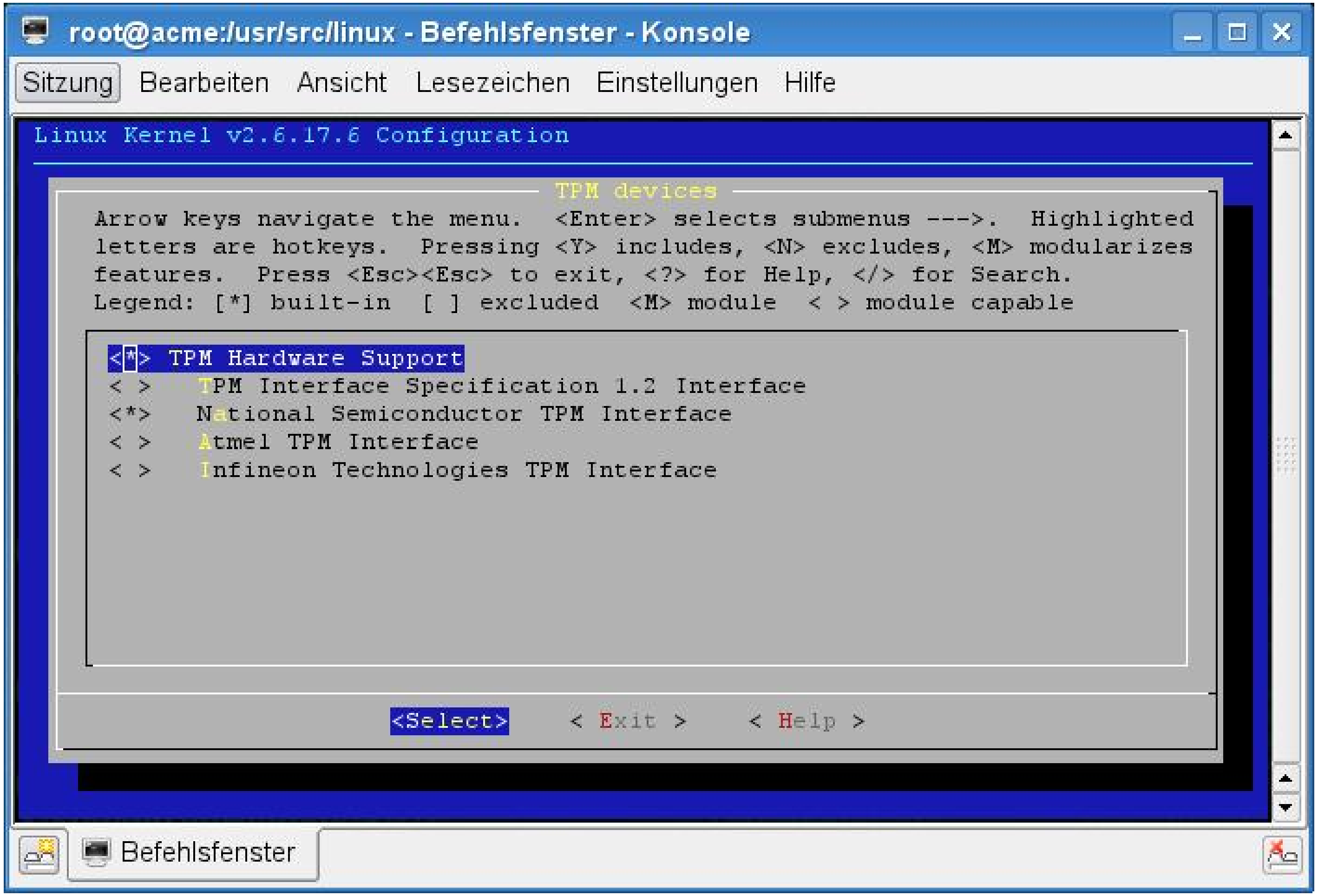
TPM device drivers (5)



TPM device drivers (6)



TPM device drivers (7)



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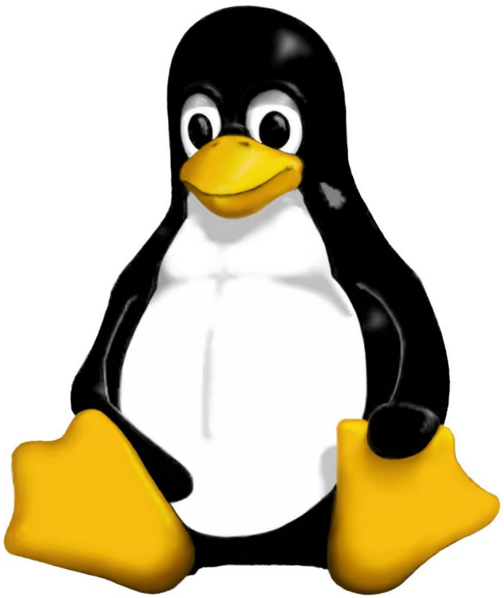
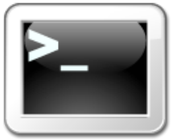
TPM device drivers (8)

- HP compaq 6715b laptops we are using are equipped with an Infineon TPM 1.2
- Therefore, we have two options on TPM-device drivers:
  - legacy Infineon TPM 1.2
    - `modprobe tpm_infineon`
  - Generic TIS driver for TPMs 1.2
    - `modprobe tpm_tis`
- We will use `tpm_infineon`



TPM device drivers (9)

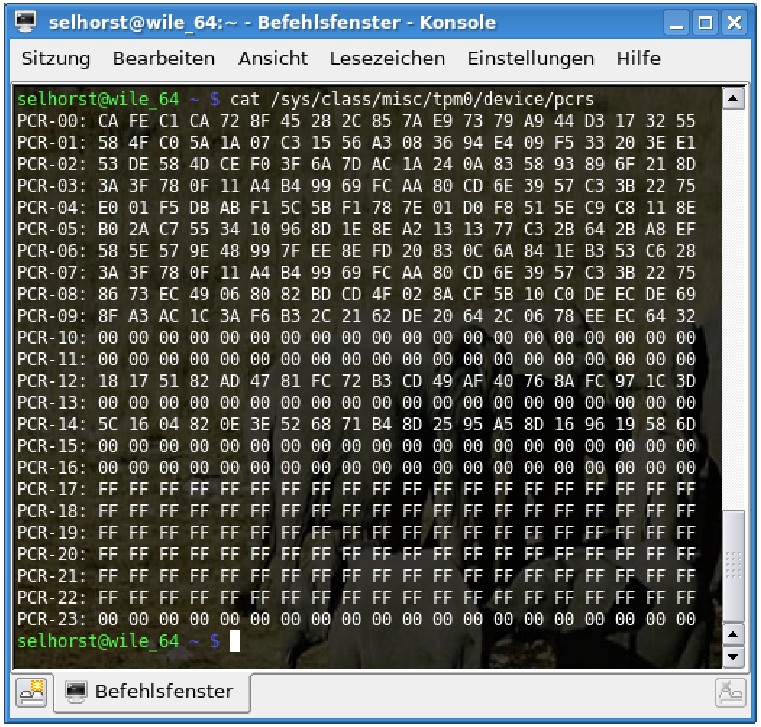
- Step 1: Open a Terminal / Konsole click on this desktop icon 
- Step 2: Load the device driver
  - `sudo modprobe tpm_infineon`
- Step 3: Verify, that the TPM device driver has loaded successfully:
  - `lsmod | grep tpm`
  - `dmesg | grep tpm`
- Step 4: Verify the existence of the correct node-device
  - `ls -l /dev/tpm0`
    `should be user:tss, 10, 224`

TPM device drivers (10)

- Step 5: Verify the existence of `sysfs`-directory
  - `ls -l /sys/class/misc/tpm0/device`
    - `caps`
    - `id`
    - `options`
    - `pcrs`
    - `pubek`
    - `resources`
    - `...`
- Now we should be able to communicate with the TPM via `/dev/tpm0`

TPM device drivers (11)

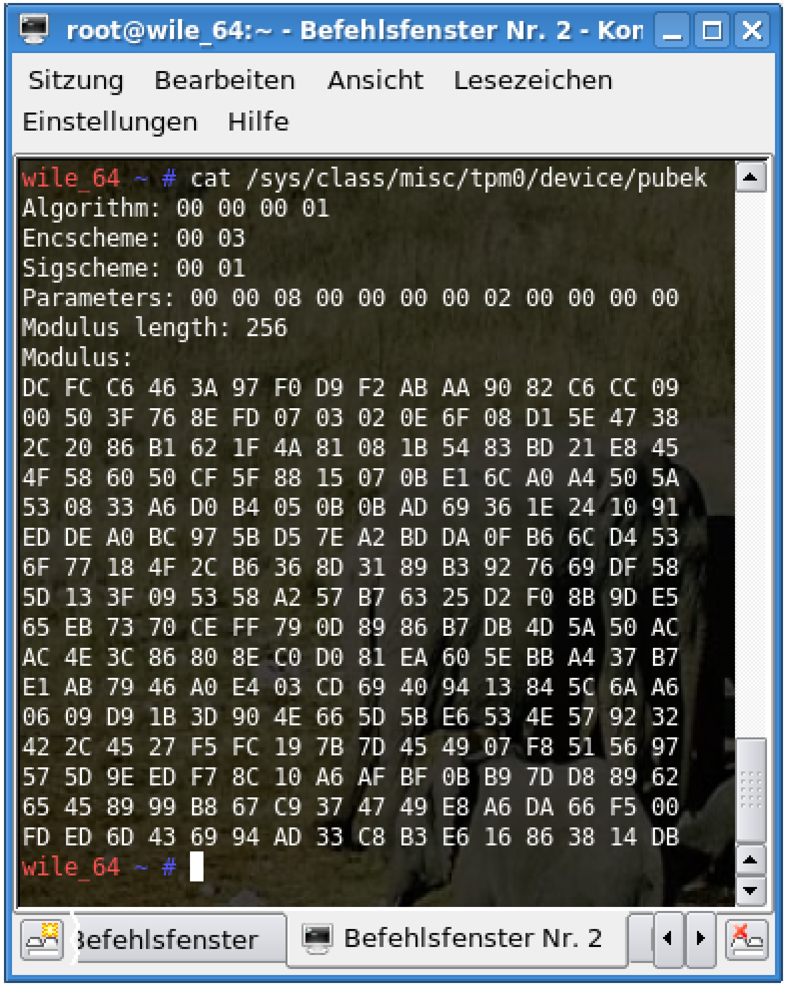
- Read out the Platform Configuration Registers (PCRs)
  - `cat /sys/class/misc/tpm0/device/pcrs`



- We will come back to PCRs in section “Chain of Trust”

TPM device drivers (12)

- Read out the Public Endorsement Key
  - `cat /sys/class/misc/tpm0/device/pubek`



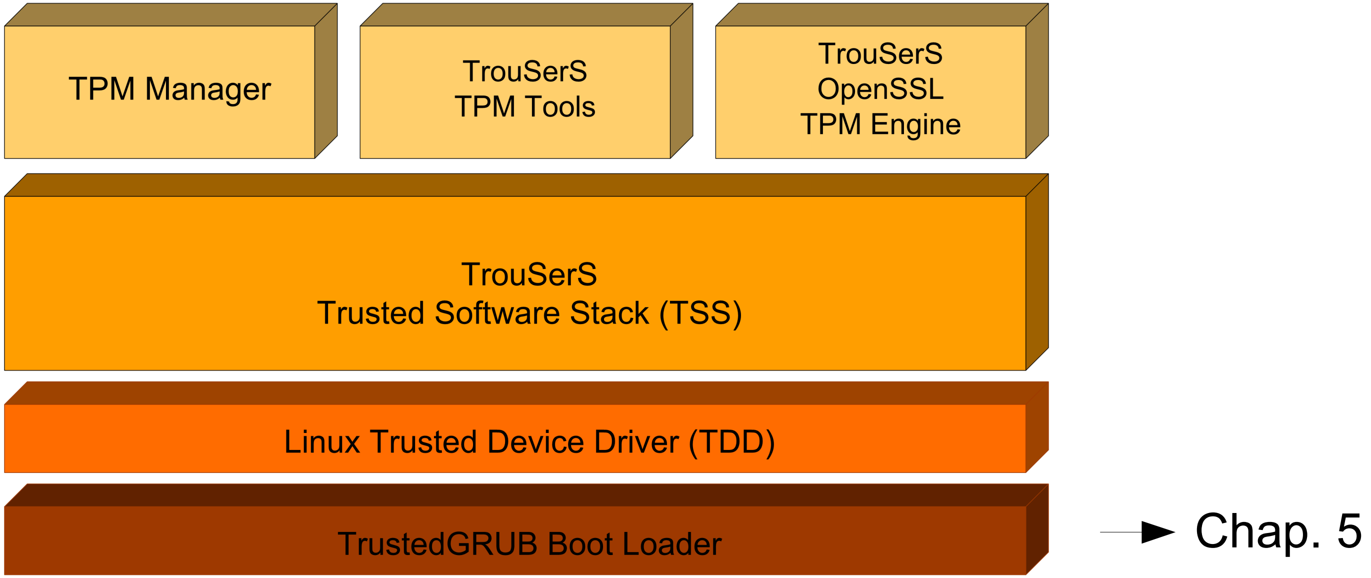
Content

TPM open source software (1)

- Available Open Source Software:
  - TrustedGRUB
    - http://sourceforge.net/projects/trustedgrub
  - TrouSerS TSS
    - http://sourceforge.net/projects/trousers
  - TPM-Tools
    - http://sourceforge.net/projects/trousers
  - OpenSSL TPM-Engine
    - http://sourceforge.net/projects/trousers
  - TPM-Manager
    - http://sourceforge.net/projects/tpmmanager

TPM open source software (2)

- Open Source Software high-level hierarchy



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    - TrouSerS
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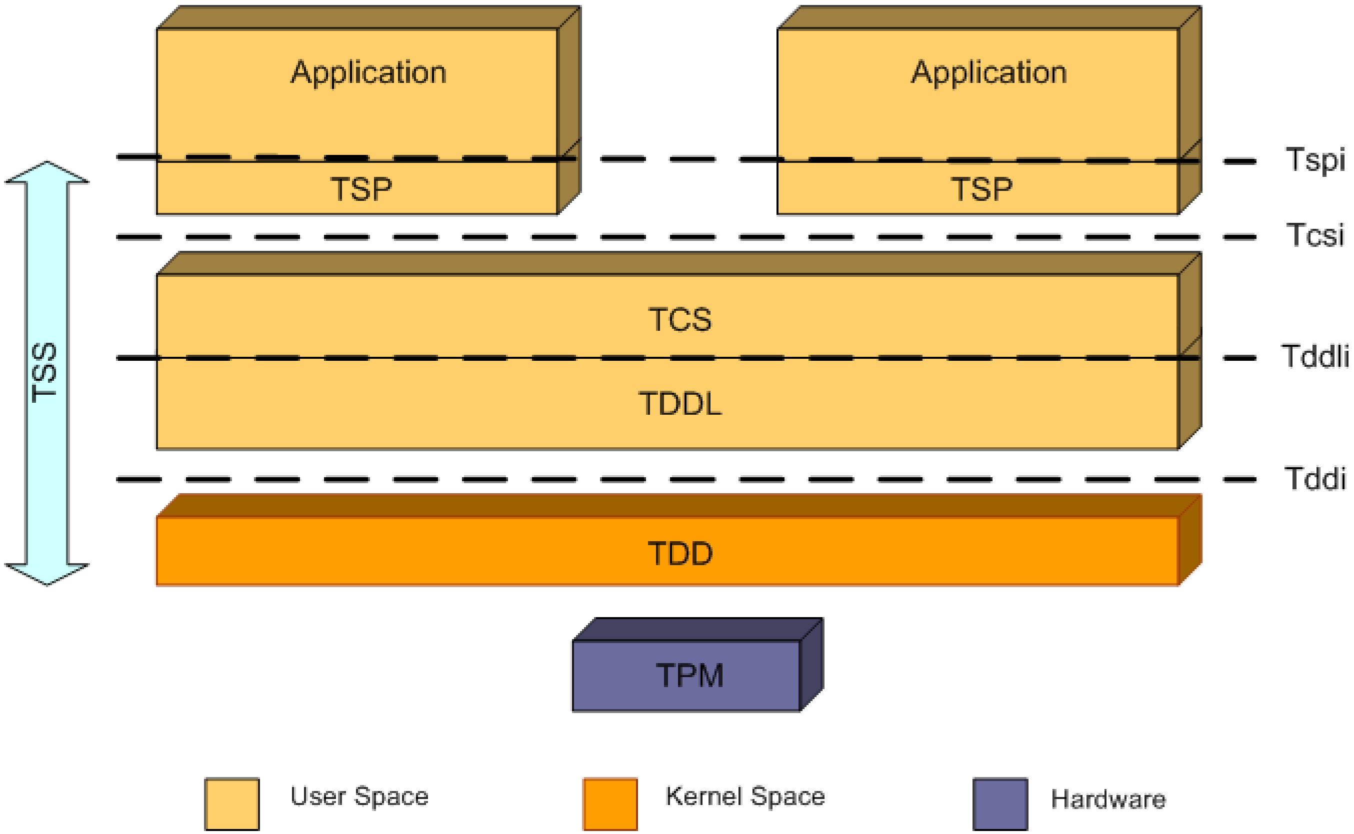
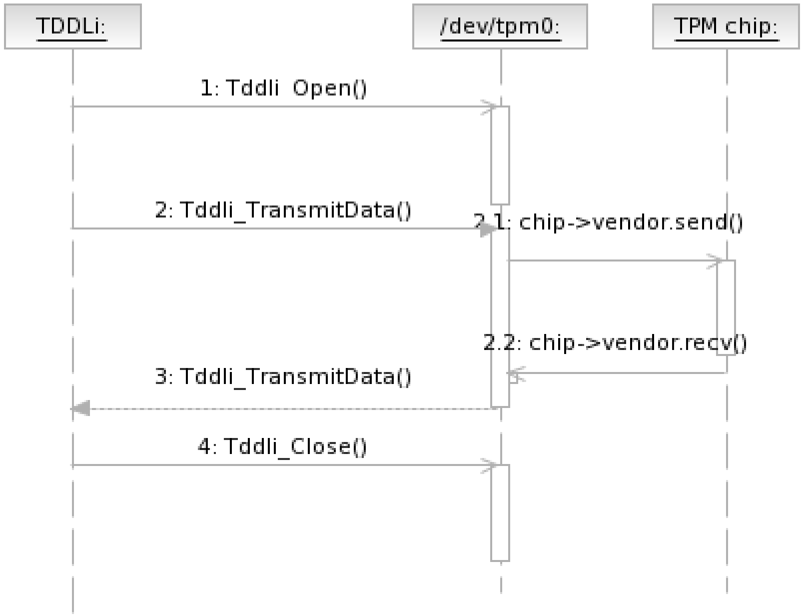
TPM open source software (3)

- TrouSerS TSS architecture



TPM open source software (4)

- TrouSerS TPM communication



TPM open source software (5)

- Start TrouSerS:

```
~$ sudo /etc/init.d/tcsd start
```

```
* Starting TrouSerS' TCS daemon (tcsd) ...   [ ok ]
```

- Start the TPM-Manager:

```
~$ tpmmanager
```

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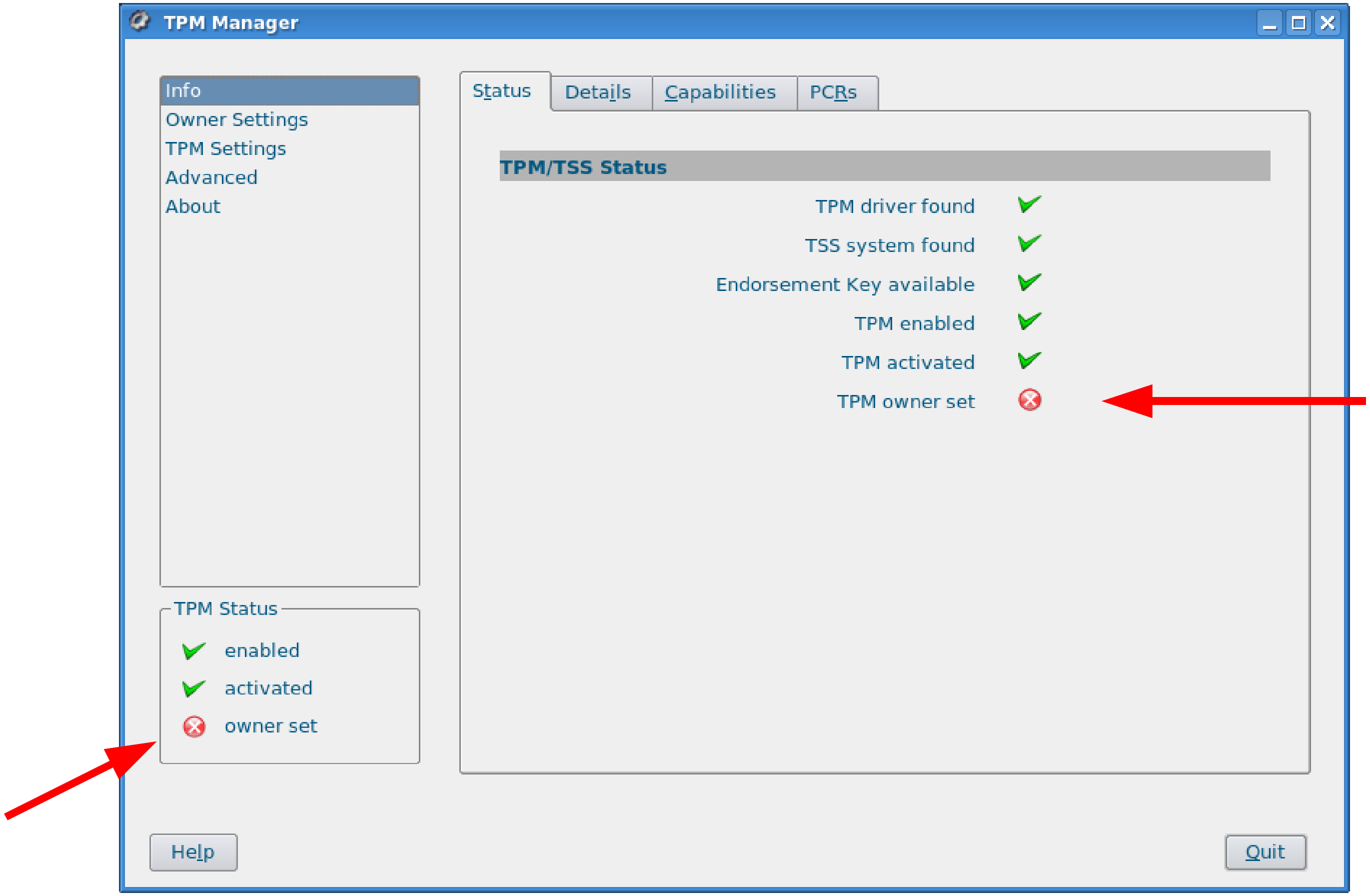
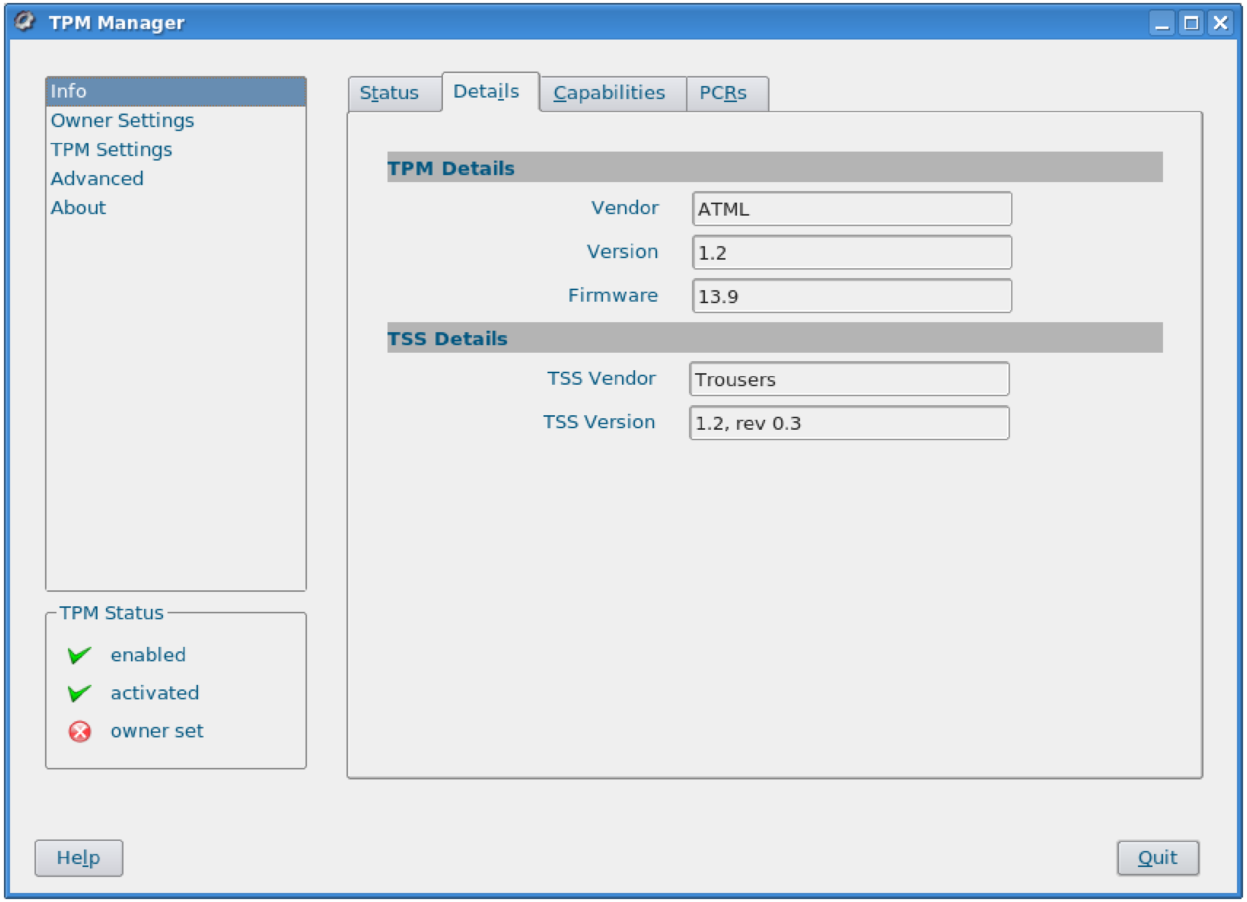
TPM open source software (6)

- TPM-Manager:



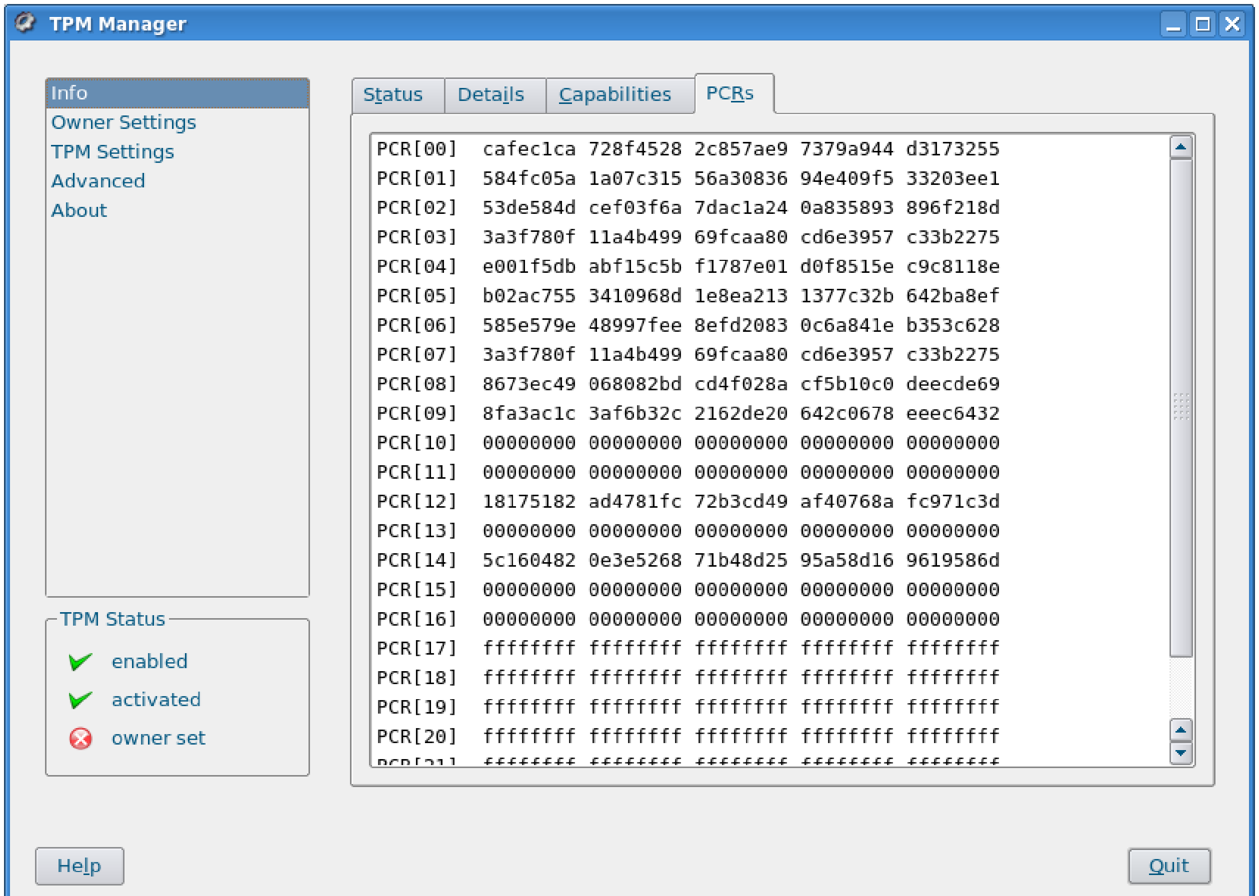
TPM open source software (7)

- TPM-Manager:



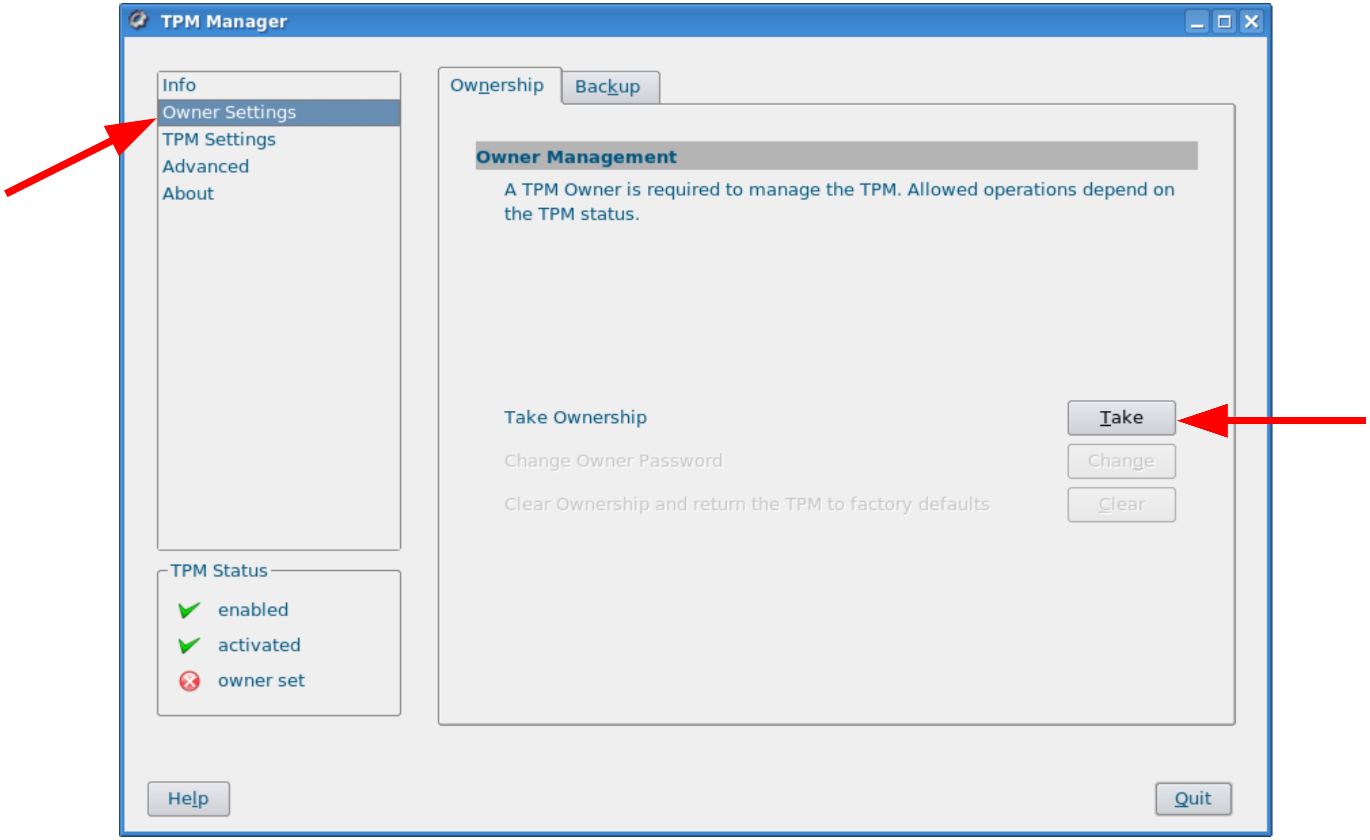
TPM open source software (8)

- TPM-Manager:



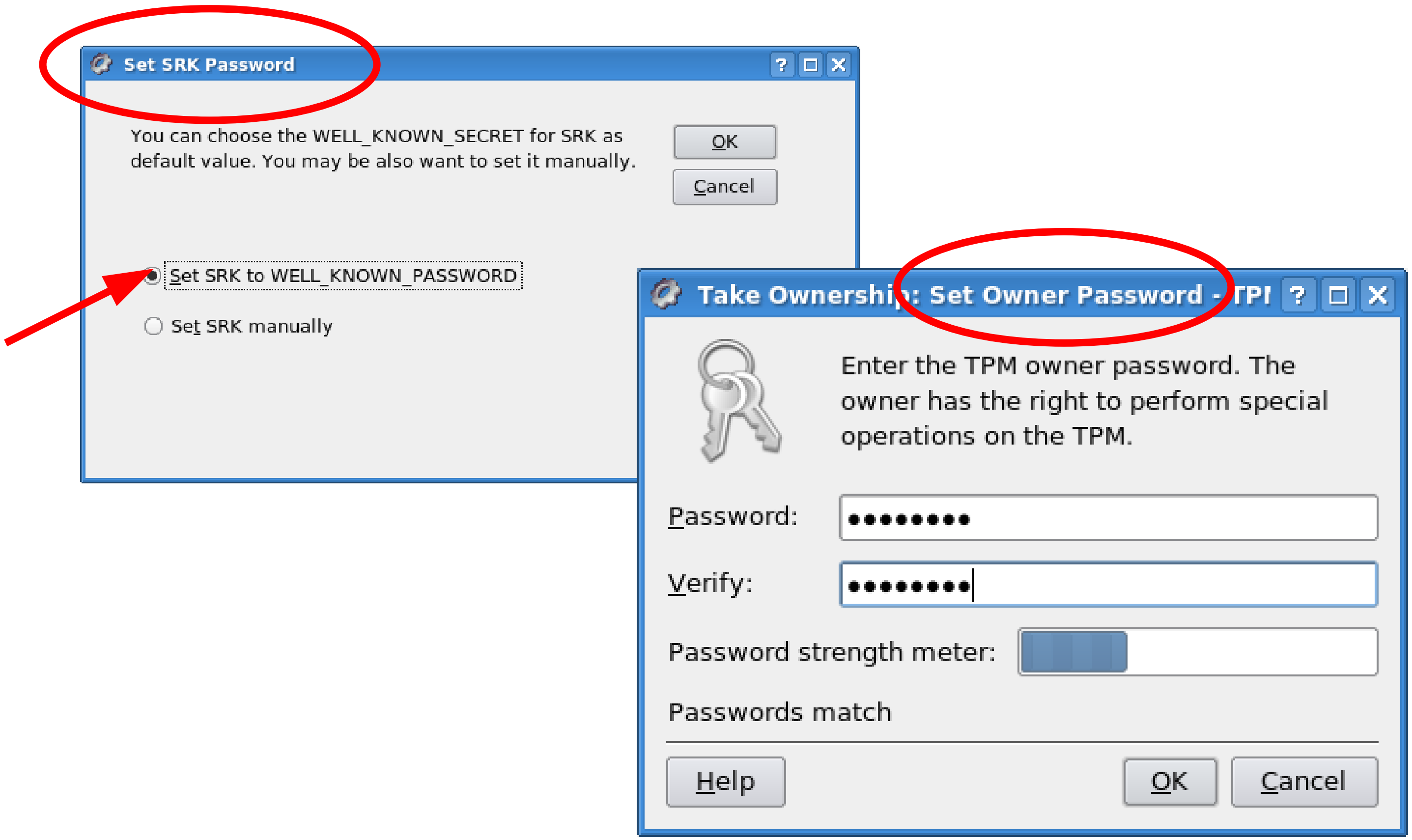
TPM open source software (9)

- Taking Ownership with the TPM-Manager:



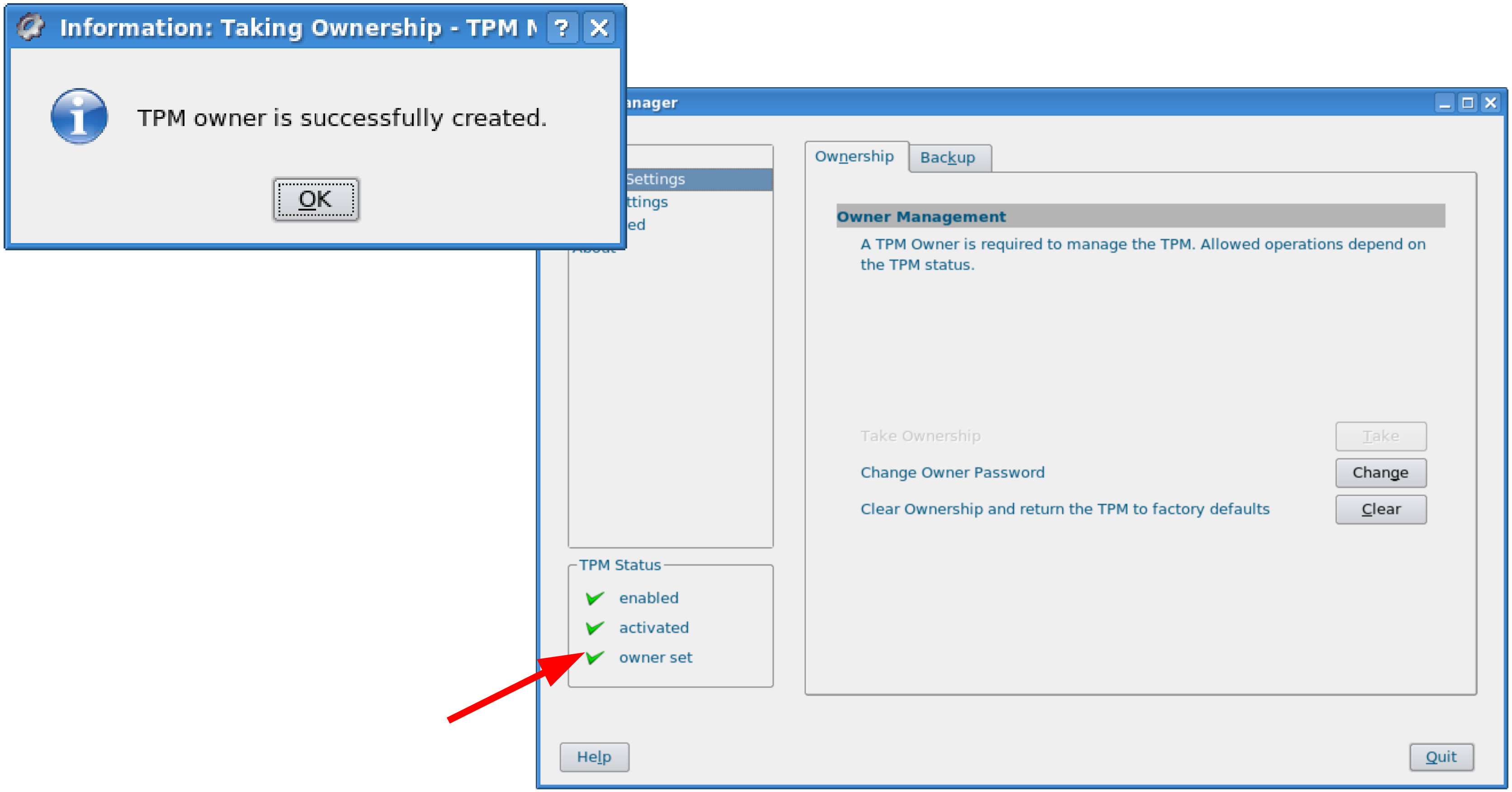
TPM open source software (10)

- Taking Ownership with the TPM-Manager:



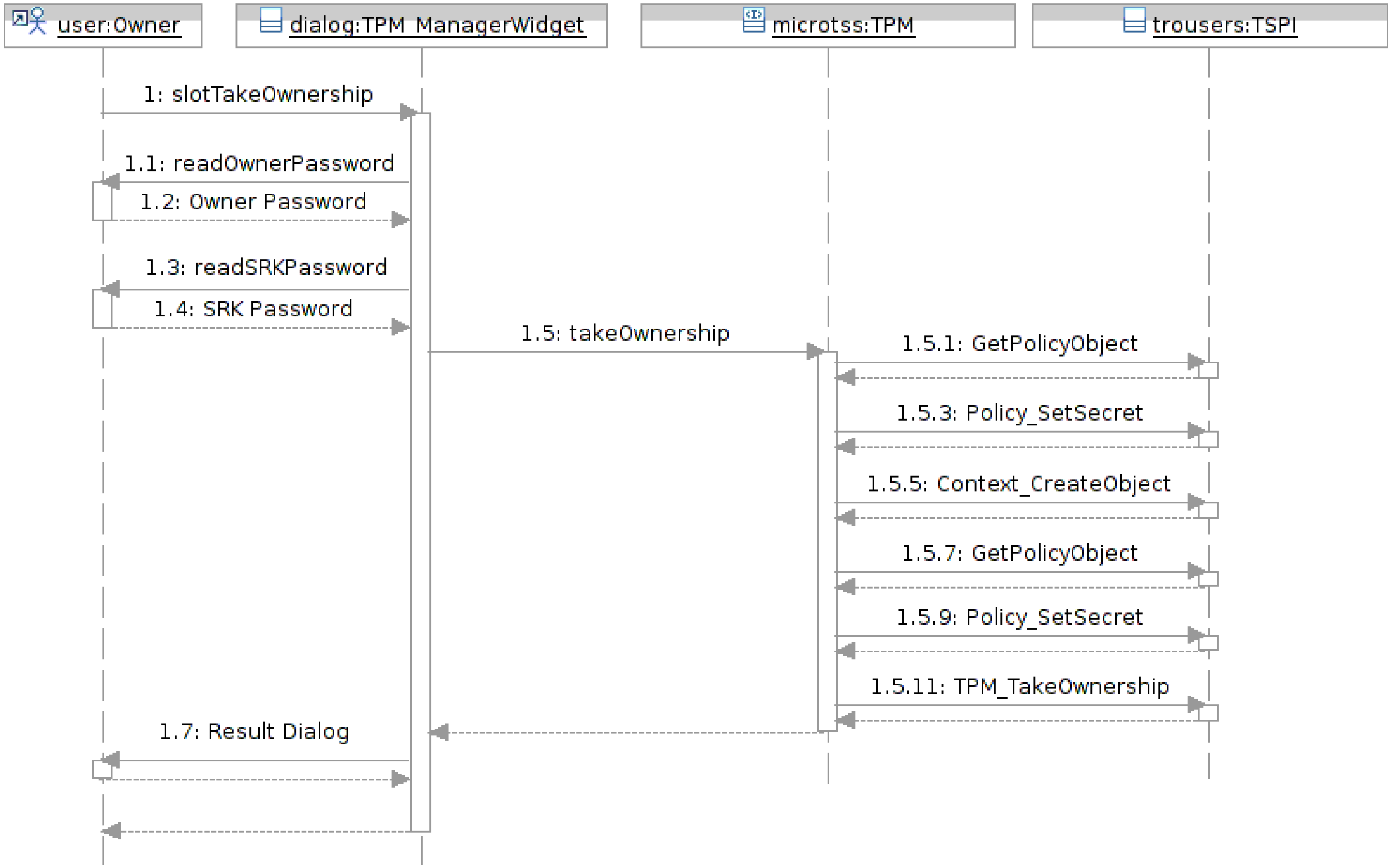
TPM open source software (11)

- Taking Ownership with the TPM-Manager:



TPM open source software (12)

- Taking Ownership – TSS interaction:



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TPM commands (1)

- The current TCG specification 1.2 rev. 103 has > 100 TPM commands
- TPM commands are classified into 5 categories
  - Mandatory
  - Optional
  - Deprecated
  - Deleted
  - Vendor-specific
- The TCG spec. part 3 defines all input and output parameters for the available commands
- The TCG spec. part 2 defines the actual values for the parameters, structures, commands etc.

TPM commands (2)

- Every command consists of at least 3 parameters:
  - `TPM_TAG` ***tag***

    -> defines the degree of authorization
  - `UINT32` ***paramSize***

    -> defines the total amount of input bytes
  - `TPM_COMMAND_CODE` ***ordinal***

    -> represents the function, the TPM shall execute
- Every TPM command will be processed by the TPM
- The TPM always responds with a return code

TPM commands (3)

- There are 1 + 4 types of return codes
- Successful operation:
  - Return code is TPM_SUCCESS (0x0)
  - Additional data might be included in the response (e.g., if a key shall be created, the response will also contain the generated key)
- Error during operation:
  - When a command fails for any reason, the TPM must return only the following 3 items:
  - TPM_TAG_RQU_COMMAND (2 bytes)
  - ParamLength(4 bytes, fixed at 10)
  - Return Code (4 bytes, never TPM_SUCCESS)

TPM commands (4)

- The return codes for errors are divided into 4 categories:
  - TPM defined fatal errors
    - (0x001 to 0x3FF)
  - Vendor defined fatal errors
    - (0x400 to 0x7FF)
  - TPM defined non-fatal errors
    - (0x800 to 0xBFF)
  - Vendor defined non-fatal errors
    - (0xC00 to 0xFFF)

TPM commands (5)

- Currently 99 TPM defined fatal errors:
  - Defined in TPM spec. part 2, pages 131ff

TPM-defined fatal error codes

Name	Value	Description
TPM_AUTHFAIL	TPM_BASE + 1	Authentication failed
TPM_BADINDEX	TPM_BASE + 2	The index to a PCR, DIR or other register is incorrect
TPM_BAD_PARAMETER	TPM_BASE + 3	One or more parameter is bad
TPM_AUDITFAILURE	TPM_BASE + 4	An operation completed successfully but the auditing of that operation failed
TPM_CLEAR_DISABLED	TPM_BASE + 5	The clear disable flag is set and all clear operations now require physical access
TPM_DEACTIVATED	TPM_BASE + 6	The TPM is deactivated
TPM_DISABLED	TPM_BASE + 7	The TPM is disabled
TPM_DISABLED_CMD	TPM_BASE + 8	The target command has been disabled
TPM_FAIL	TPM_BASE + 9	The operation failed
TPM_BAD_ORDINAL	TPM_BASE + 10	The ordinal was unknown or inconsistent
TPM_INSTALL_DISABLED	TPM_BASE + 11	The ability to install an owner is disabled
TPM_INVALID_KEYHANDLE	TPM_BASE + 12	The key handle can not be interpreted
TPM_KEYNOTFOUND	TPM_BASE + 13	The key handle points to an invalid key

TPM commands (6)

- Example of the input / output parameters of the TPM command `TPM_PCRRead`

PARAM #	PARAM SZ	HMAC #	HMAC SZ	Type	Name	Description
1	2			TPM_TAG	tag	TPM_TAG_RQU_COMMAND
2	4			UINT32	paramSize	Total number of input bytes including paramSize and tag
3	4	1S	4	TPM_COMMAND_CODE	ordinal	Command ordinal TPM_ORD_PCRRead
4	4	2S	4	TPM_PCRINDEX	pcrIndex	Index of the PCR to be read

Outgoing Operands and Sizes

PARAM #	PARAM SZ	HMAC #	HMAC SZ	Type	Name	Description
1	2			TPM_TAG	tag	TPM_TAG_RSP_COMMAND
2	4			UINT32	paramSize	Total number of output bytes including paramSize and tag
3	4	1S	4	TPM_RESULT	returnCode	The return code of the operation.
		2S	4	TPM_COMMAND_CODE	ordinal	Command ordinal TPM_ORD_PCRRead
4	20	3S	20	TPM_PCRVALUE	outDigest	The current contents of the named PCR

TPM commands – exercises

- Now we are going to write some TPM commands
- The needed TCG specification is located at:

  `/home/etiss/Desktop/exercise/spec`
- There are two different versions available, since the latest revision 103 didn't update the table-of-content
- Before executing any of the commands, the TrouSerS-daemon `tcsd` has to be stopped!
  - `sudo /etc/init.d/tcsd stop`
- Since the permissions on `/dev/tpm0` belong to TrouSerS, we have to change this in order to gain read-write-access to the TPM device:
  - `sudo chmod 666 /dev/tpm0`

TPM commands – exercise 1

- `/home/etiss/Desktop/exercise/code1/` contains a code skeleton using the TPM-command `TPM_GetCapability`. Please fill out the missing **capability parameters:**

```
#define     TPM_CAP_PROPERTY
#define     TPM_CAP_VERSION_VAL
#define     TPM_CAP_PROP_MANUFACTURER
#define     TPM_CAP_PROP_OWNER
```

  - `make`
  - `./tpm_getcapabilities`

TPM commands – exercise 2

- `/home/etiss/Desktop/exercise/code2/` contains a code skeleton of the TPM-command `TPM_Extend`. This code will hash a file and extend it into the defined PCR. Please fill out the missing **command parameters:**

```
#define TPM_EXTEND_TAG
#define TPM_EXTEND_PARAMSIZE
#define TPM_EXTEND_ORDINAL
#define TPM_EXTEND_PCR_INDEX
```

- `make`
- `./extend_pcr <some filename>`

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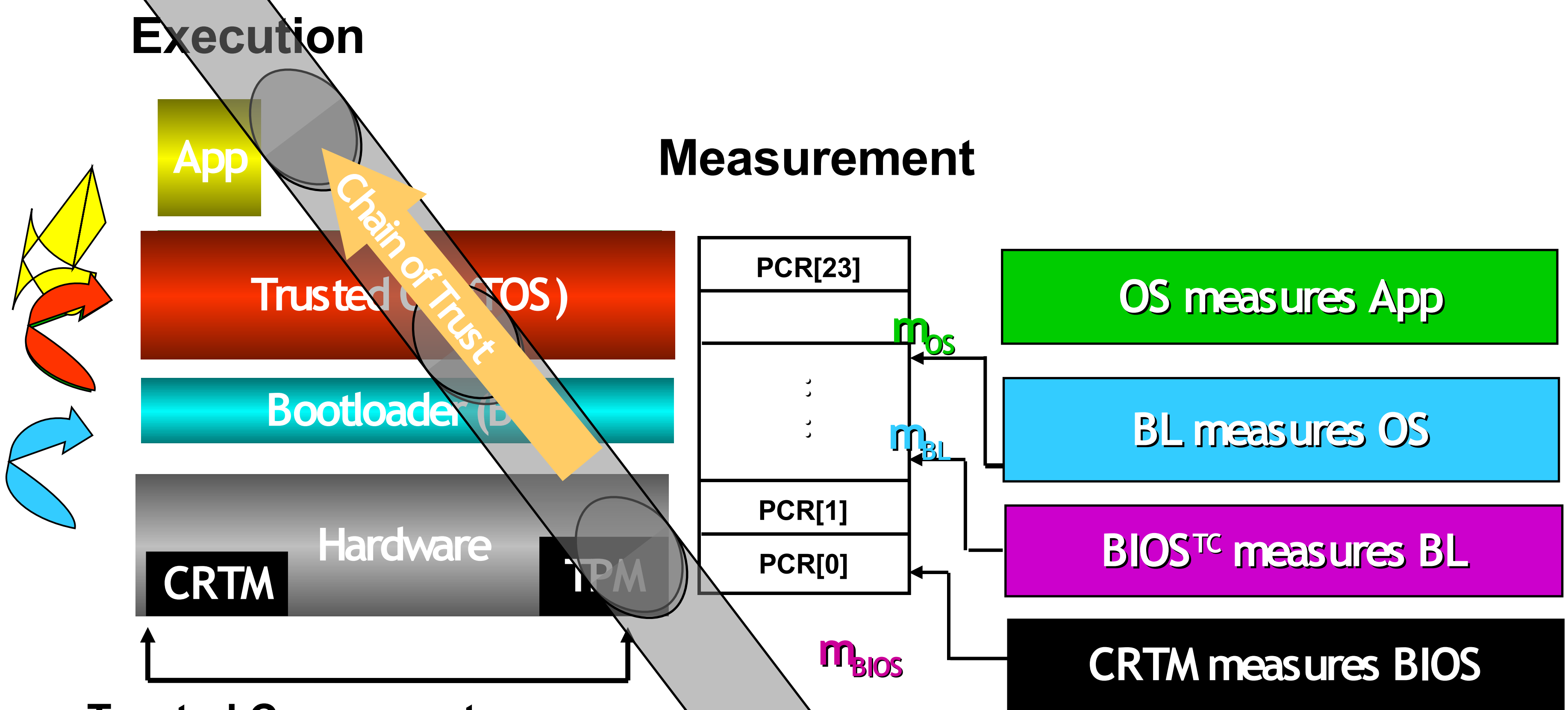
- Instantiation based on TCG approach



Trusted Components:

- Core Root of Trust for Measurement (CRTM)
- Trusted Platform Module (TPM)

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The Chain of Trust (2)

- New TCG BIOS commands added
  - Examples
    - TCG_StatusCheck: Checks whether a TPM is available
    - TCG_HashAll: Computes SHA1 hashes of given input data (boot loader)
    - TCG_PassThroughToTPM: Sends TPM commands to the TPM via BIOS TPM Driver
    - …
  - Command calls via Interrupt 0x1Ah
- All commands have an Input Parameter Block (IPB) and an Output Parameter Block (OPB)

The Chain of Trust (3)
Detailed TCG BIOS Example

- TCG_PassThroughToTPM
- IPB: contains TPM command and parameters as specified in TCG specification (e.g., TPM_Extend)

- On Entry:

Ah: 0xBB	// TCG command
Al: 0x02	// Function selector (here TCG_PassThroughToTPM)
ES:DI:	// Pointer to IPB
DS:SI:	// Pointer to OPB
EBX: 0x41504354	// ‚TCPA‘
ECX: 0	
EDX: 0	
Int: 0x1A	// Interrupt

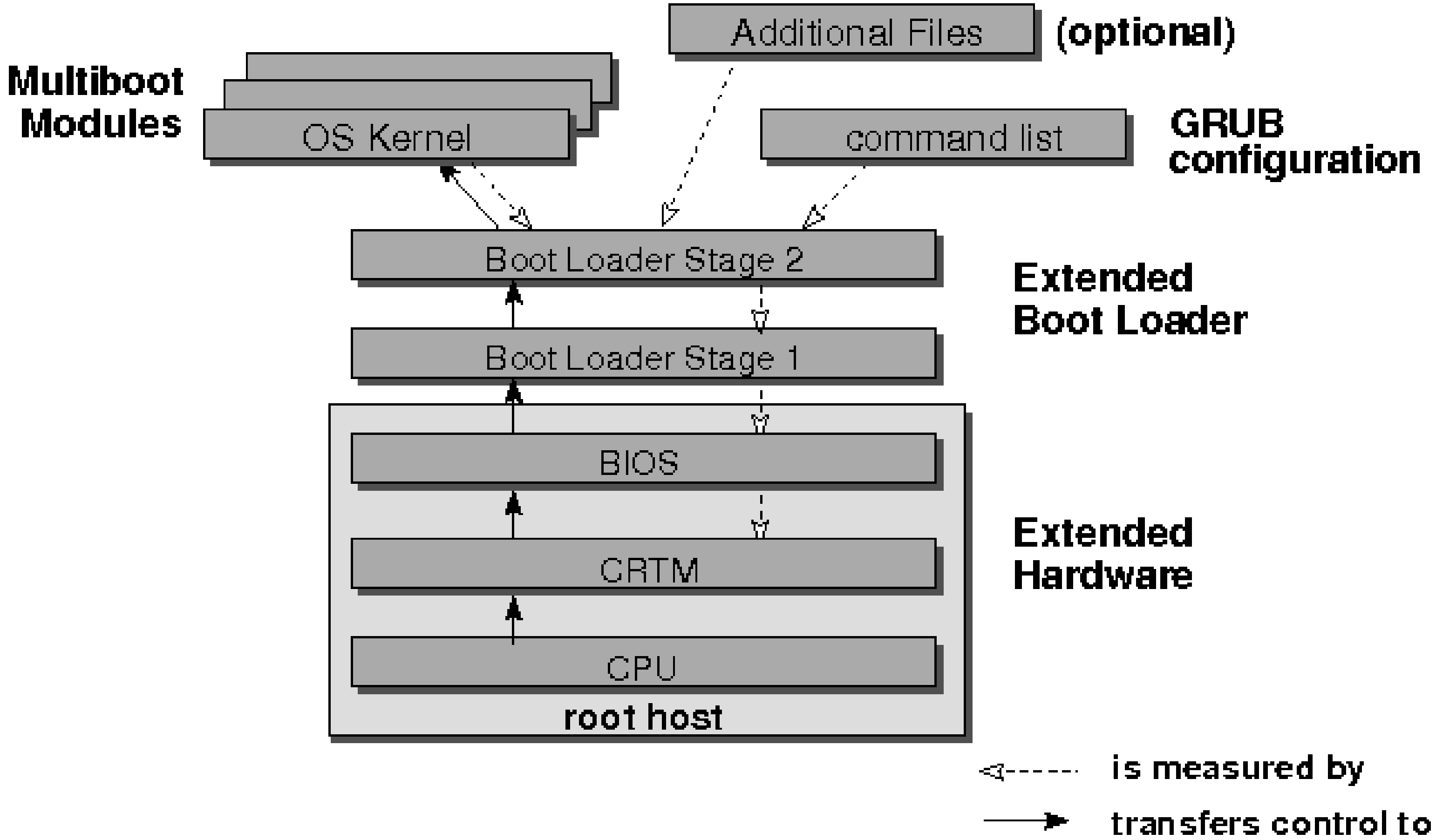
- On Return:

  EAX: TCG BIOS Return code
  DS:SI: Updated reference buffer (OPB)

The Chain of Trust (4) - TrustedGRUB

- According to TCG Specification measurements performed up to MBR
- TrustedGRUB extends the common available GRUB boot loader with mechanisms realizing authenticated boot up to OS
  - TrustedGRUB = TCG extended BIOS (CRTM) + GRUB + TPM functions
  - “stage1” measures subsequent stage “stage2”
  - “stage2” measures OS components (e.g., kernel), configuration file and optionally any additional files
- No direct communication with TPM
  - applies BIOS-calls instead (defined by the TCG)

The Chain of Trust (5) - TrustedGRUB



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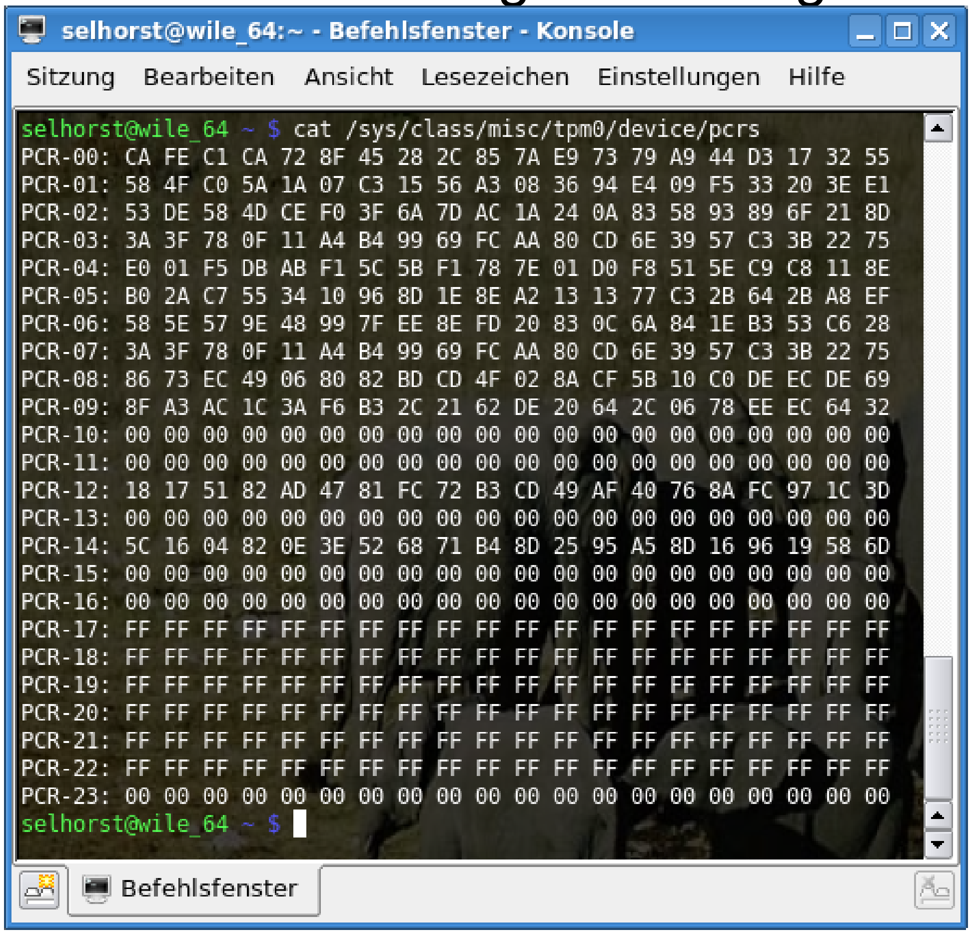
The Chain of Trust (6) - TrustedGRUB

- Platform Configuration Registers (PCRs)




```
selhorst@wile_64 ~ $ cat /sys/class/misc/tpm0/device/pcrs
PCR-00: CA FE C1 CA 72 8F 45 28 2C 85 7A E9 73 79 A9 44 D3 17 32 55
PCR-01: 58 4F C0 5A 1A 07 C3 15 56 A3 08 36 94 E4 09 F5 33 20 3E E1
PCR-02: 53 DE 58 4D CE F0 3F 6A 7D AC 1A 24 0A 83 58 93 89 6F 21 8D
PCR-03: 3A 3F 78 0F 11 A4 B4 99 69 FC AA 80 CD 6E 39 57 C3 3B 22 75
PCR-04: E0 01 F5 DB AB F1 5C 5B F1 78 7E 01 D0 F8 51 5E C9 C8 11 8E
PCR-05: B0 2A C7 55 34 10 96 8D 1E 8E A2 13 13 77 C3 2B 64 2B A8 EF
PCR-06: 58 5E 57 9E 48 99 7F EE 8E FD 20 83 0C 6A 84 1E B3 53 C6 28
PCR-07: 3A 3F 78 0F 11 A4 B4 99 69 FC AA 80 CD 6E 39 57 C3 3B 22 75
PCR-08: 86 73 EC 49 06 80 82 BD CD 4F 02 8A CF 5B 10 C0 DE EC DE 69
PCR-09: 8F A3 AC 1C 3A F6 B3 2C 21 62 DE 20 64 2C 06 78 EE EC 64 32
PCR-10: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
PCR-11: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
PCR-12: 18 17 51 82 AD 47 81 FC 72 B3 CD 49 AF 40 76 8A FC 97 1C 3D
PCR-13: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
PCR-14: 5C 16 04 82 0E 3E 52 68 71 B4 8D 25 95 A5 8D 16 96 19 58 6D
PCR-15: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
PCR-16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
PCR-17: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-18: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-19: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-20: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-21: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-22: FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
PCR-23: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
selhorst@wile_64 ~ $
```

Platform Configuration Register

00: BIOS
01: Mainboard Configuration
02: Option ROM
03: Option ROM Configuration
04: Initial Program Loader (IPL)
05: IPL Config & Data
06: RFU (Reserved for Future Usage)
07: RFU
08: First part of „stage2“
09: Rest of „stage2“
12: Commandline parameters
13: Arbitrary file measurements
14: Booted system files
(e.g., Kernel, modules,...)
17-22: Resettable PCRs for DRTM

The Chain of Trust (7) - TrustedGRUB

- Platform Configuration Registers represent the current platform state
- The platform can only be trustworthy, if a complete, uninterrupted chain-of-trust exists
- PCRs can only be extended and are not resettable until platforms reboot (except for PCRs 17-22 in TPMs 1.2)
- By extending a PCR with a new measurement, the resulting value will be:

$$PCR_{new} = SHA1(PCR_{old} \,||\, newValue)$$

The Chain of Trust (8) - TrustedGRUB

- To verify the content of PCRs 13 and 14 a tool exists called:

```
verify_pcr
```

- Usage:

```
~ $ verify_pcr <initial PCR> <files 1-n>
```

- Example:

```
~ $ verify_pcr NULL /boot/vmlinuz
Result for PCR:
5c 16 04 82 0e 3e 52 68 71 b4
8d 25 95 a5 8d 16 96 19 58 6d
```

Thank you!
Any Questions?

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