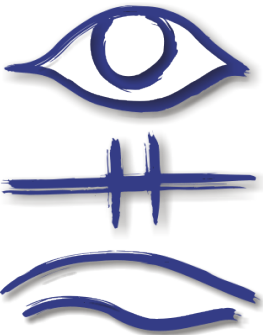




Sirrix AG security technologies



TPM Laboratory I

Marcel Selhorst
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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

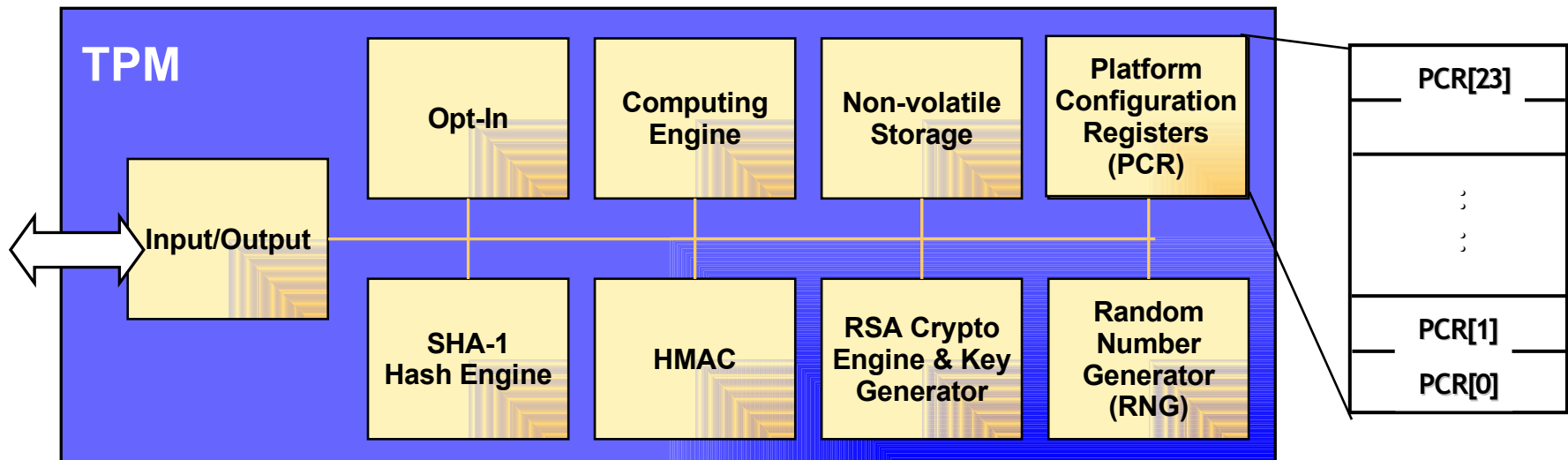
- Introduction to TPMs
- Platform Integration
- Using the TPM with Linux
- TPM commands
- The Chain of Trust

Content

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

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:

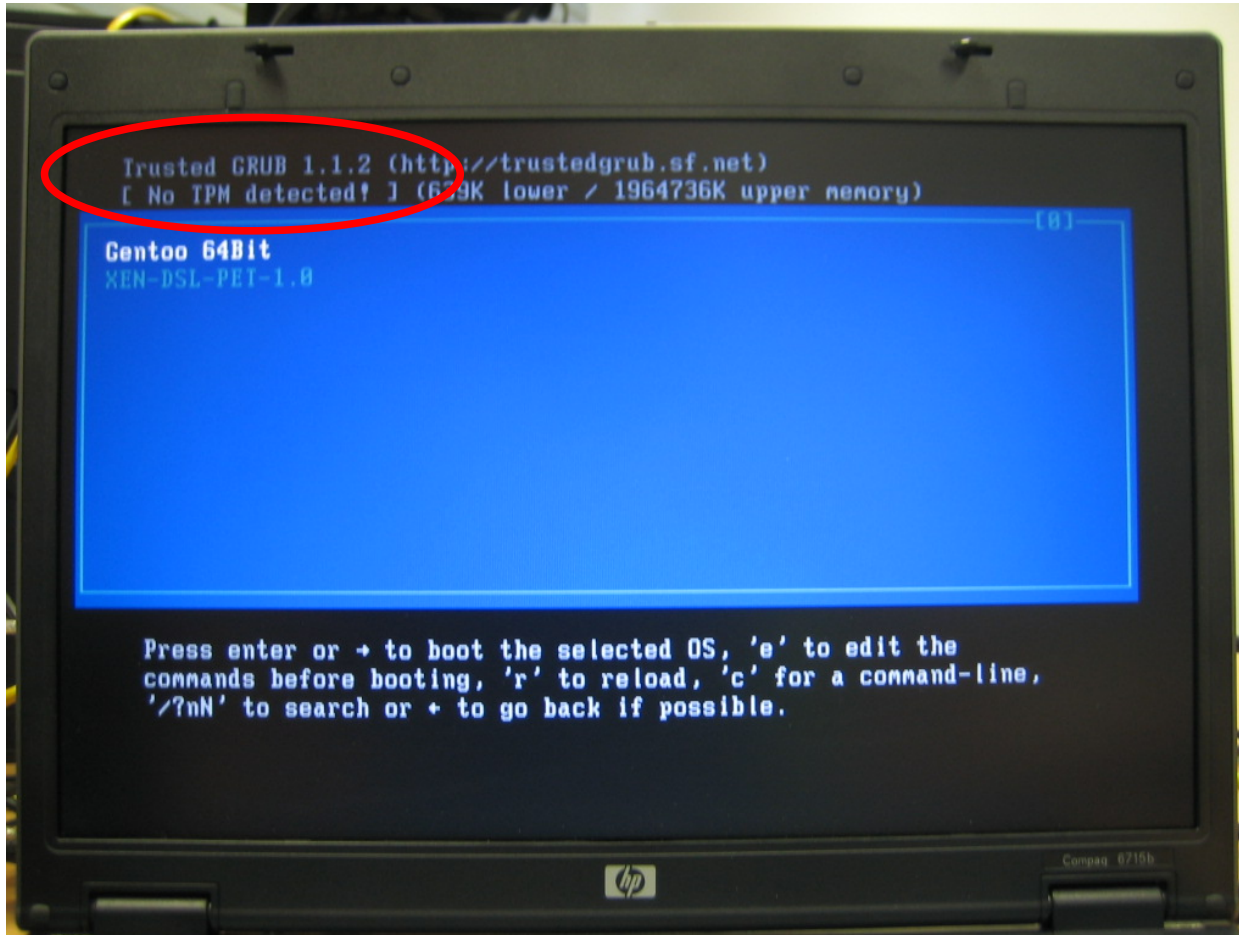
S1 – Enabled – Active – Owned
S2 – Disabled – Active – Owned
S3 – Enabled – Inactive – Owned
S4 – Disabled – Inactive – Owned
S5 – Enabled – Active – Unowned
S6 – Disabled – Active – Unowned
S7 – Enabled – Inactive – Unowned
S8 – Disabled – Inactive – Unowned

Content

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

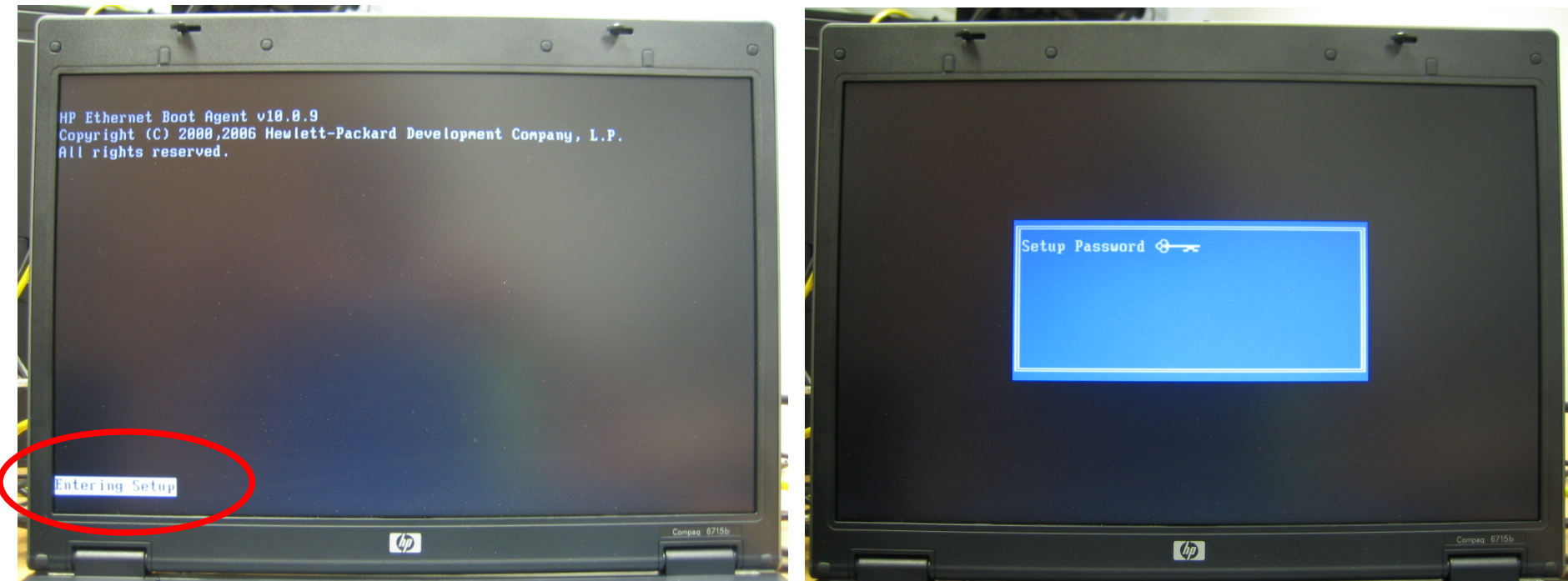
Platform Integration (1)

- 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“



Platform Integration (4)

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



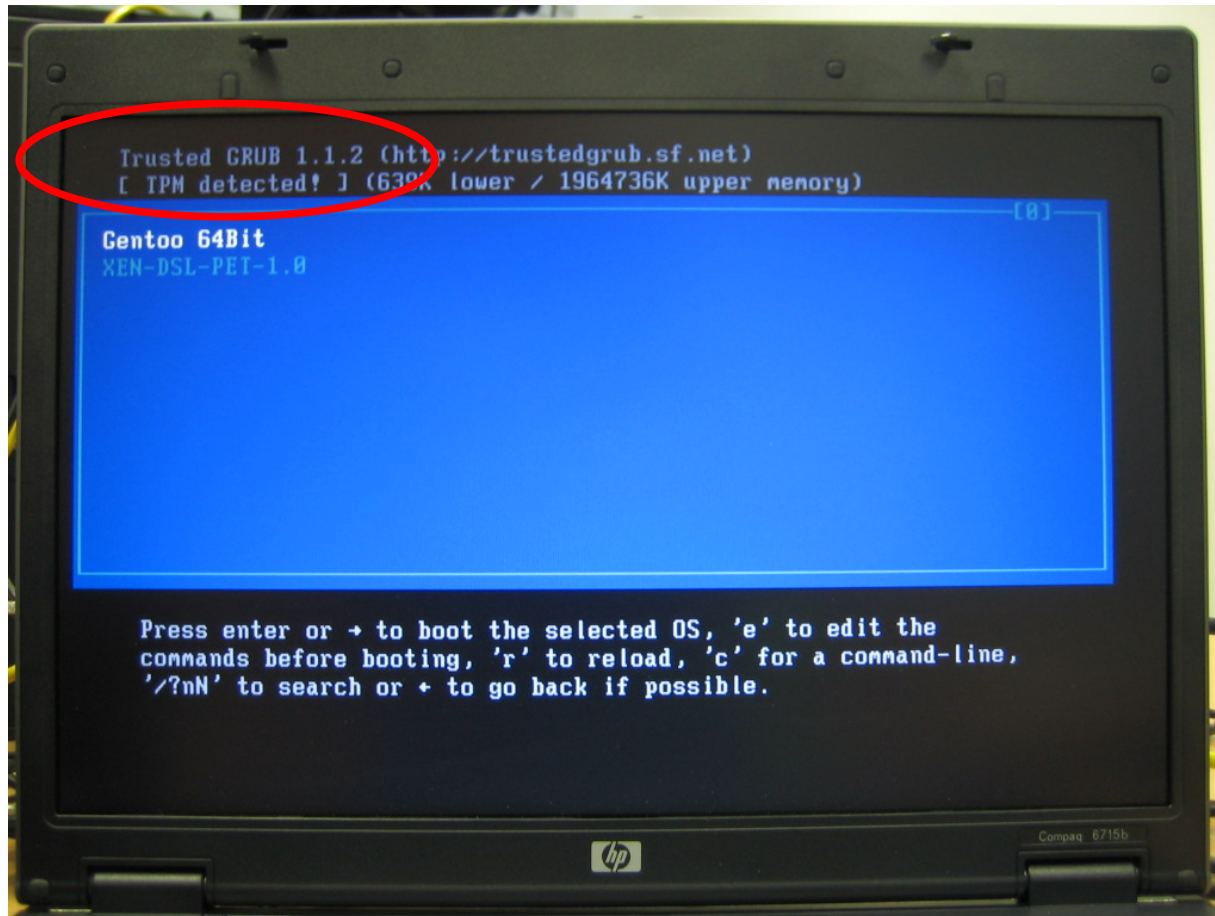
Platform Integration (5)

- Enable the TPM in the BIOS
 - Press "F1" to Accept



Platform Integration (6)

- Now the TPM should be available and detected!

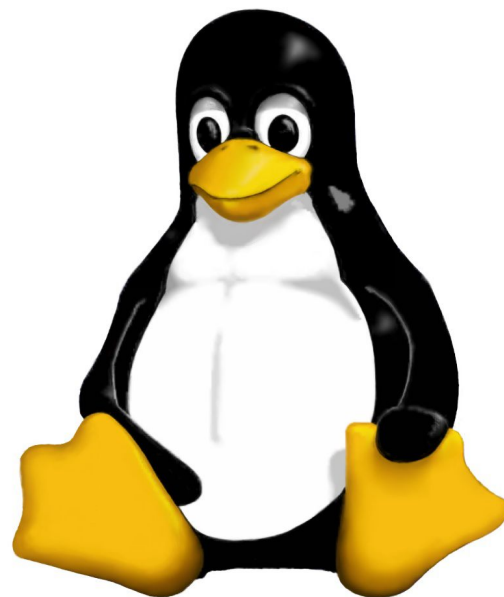


Content

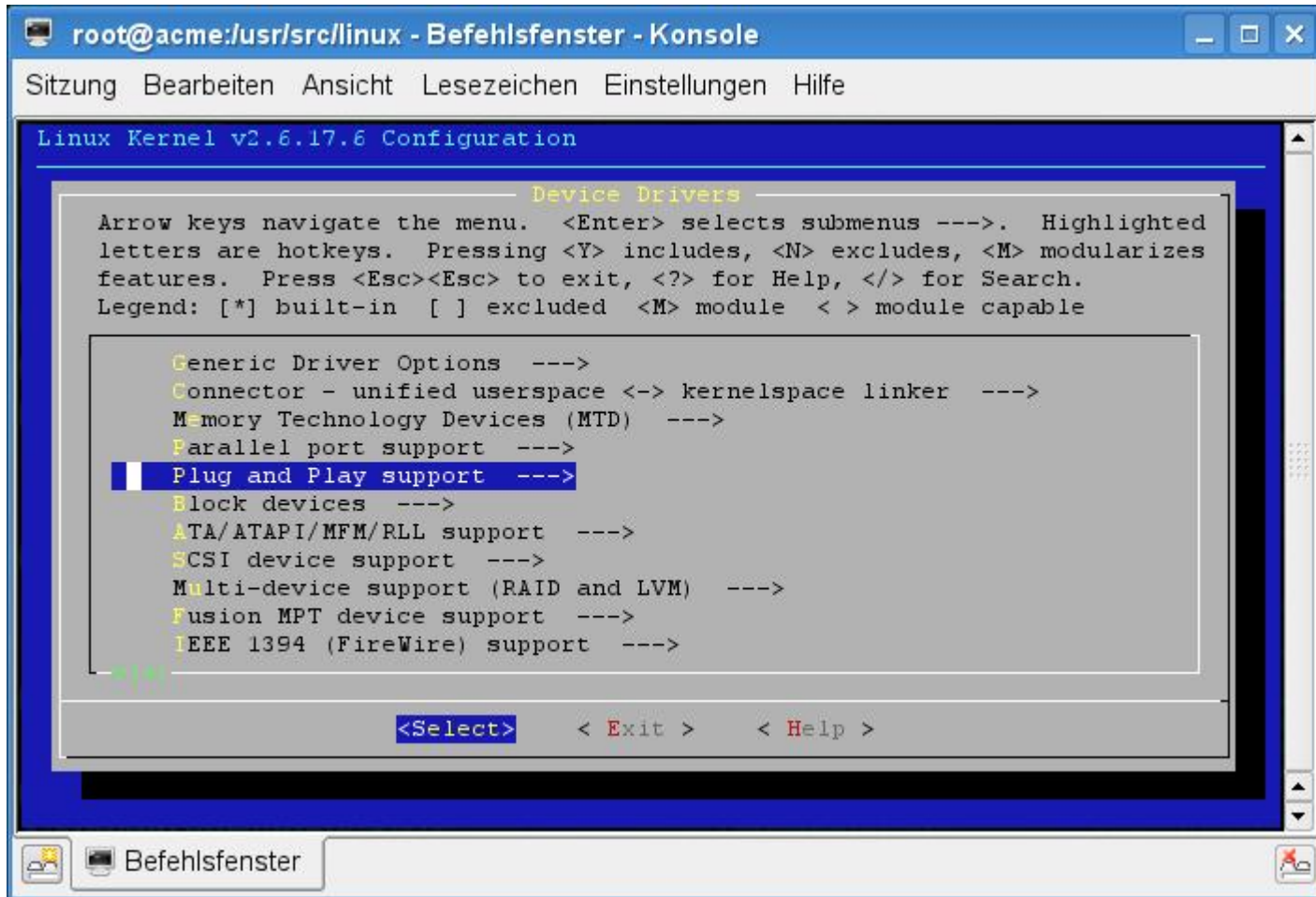
- Introduction to TPMs
- Platform Integration
- **Using the TPM with Linux**
 - **TPM device drivers**
 - TPM open source software
 - TrouSerS
 - Taking Ownership with TPM-Manager
- TPM commands
- The Chain of Trust

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`



TPM device drivers (2)



```
root@acme:/usr/src/linux - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe

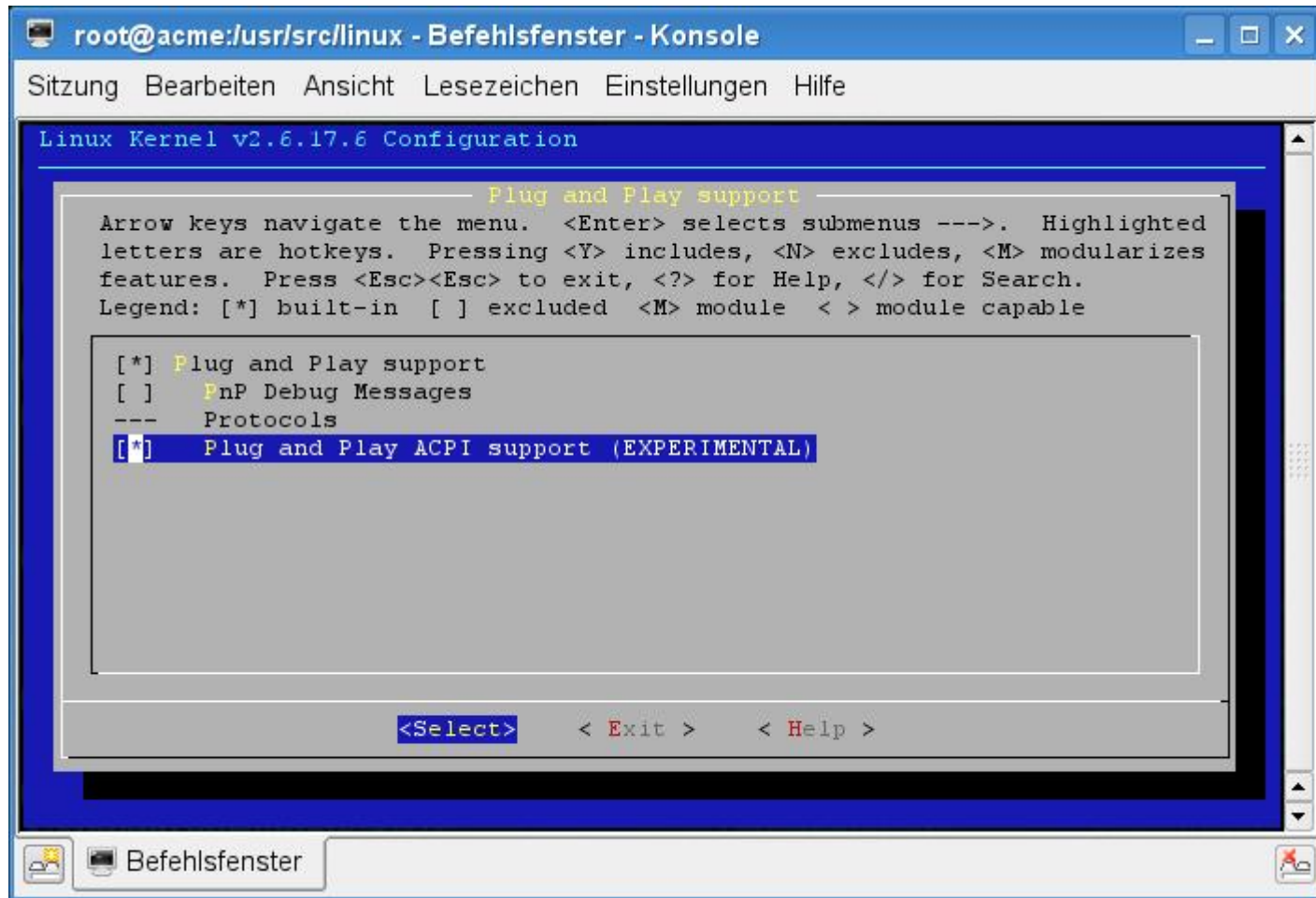
Linux Kernel v2.6.17.6 Configuration

----- Device Drivers -----
Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted
letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes
features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

Generic Driver Options --->
Connector - unified userspace <-> kernel-space linker --->
Memory Technology Devices (MTD) --->
Parallel port support --->
Plug and Play support --->
Block devices --->
ATA/ATAPI/MFM/RLL support --->
SCSI device support --->
Multi-device support (RAID and LVM) --->
Fusion MPT device support --->
IEEE 1394 (FireWire) support --->

<Select> <Exit> <Help>
```

TPM device drivers (3)



The screenshot shows a terminal window titled "root@acme:/usr/src/linux - Befehlsfenster - Konsole". The window displays the "Linux Kernel v2.6.17.6 Configuration" menu. The current selection is "Plug and Play ACPI support (EXPERIMENTAL)", which is highlighted in blue. The menu is titled "Plug and Play support" and includes instructions on how to navigate and select options. The legend indicates that [*] means built-in, [] means excluded, <M> means module, and <> means module capable. The bottom of the window shows navigation options: <Select>, <Exit >, and <Help >.

```
root@acme:/usr/src/linux - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe

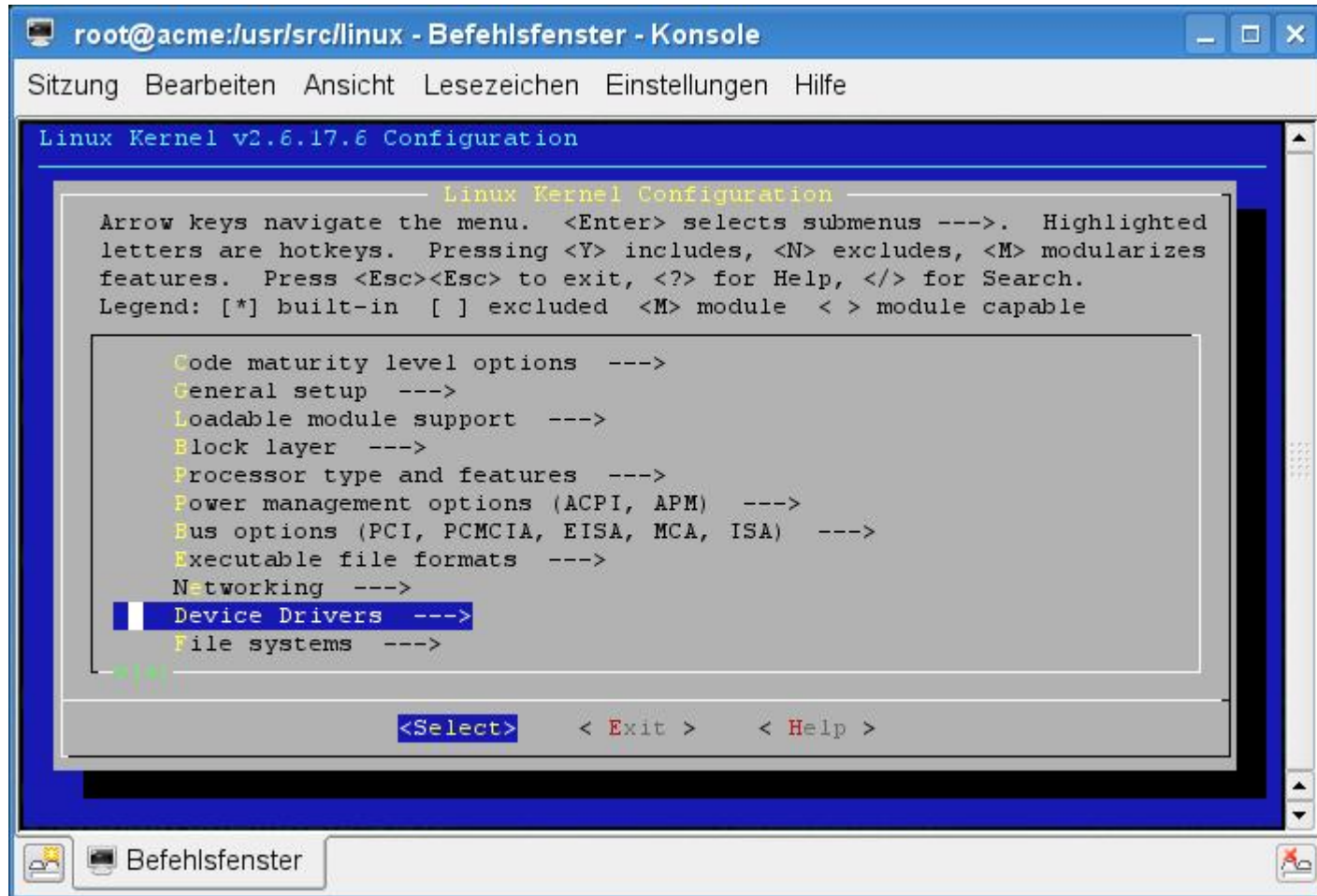
Linux Kernel v2.6.17.6 Configuration

----- Plug and Play support -----
Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted
letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes
features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module <> module capable

[*] Plug and Play support
[ ] PnP Debug Messages
--- Protocols
[*] Plug and Play ACPI support (EXPERIMENTAL)

<Select> <Exit > <Help >
```

TPM device drivers (4)



The screenshot shows a terminal window titled "root@acme:/usr/src/linux - Befehlsfenster - Konsole". The main content is the "Linux Kernel v2.6.17.6 Configuration" menu. The menu is a list of options, each followed by "---->". The "Device Drivers" option is highlighted with a blue bar. At the bottom of the menu, there are three options: "<Select>", "<Exit >", and "<Help >".

```
root@acme:/usr/src/linux - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe

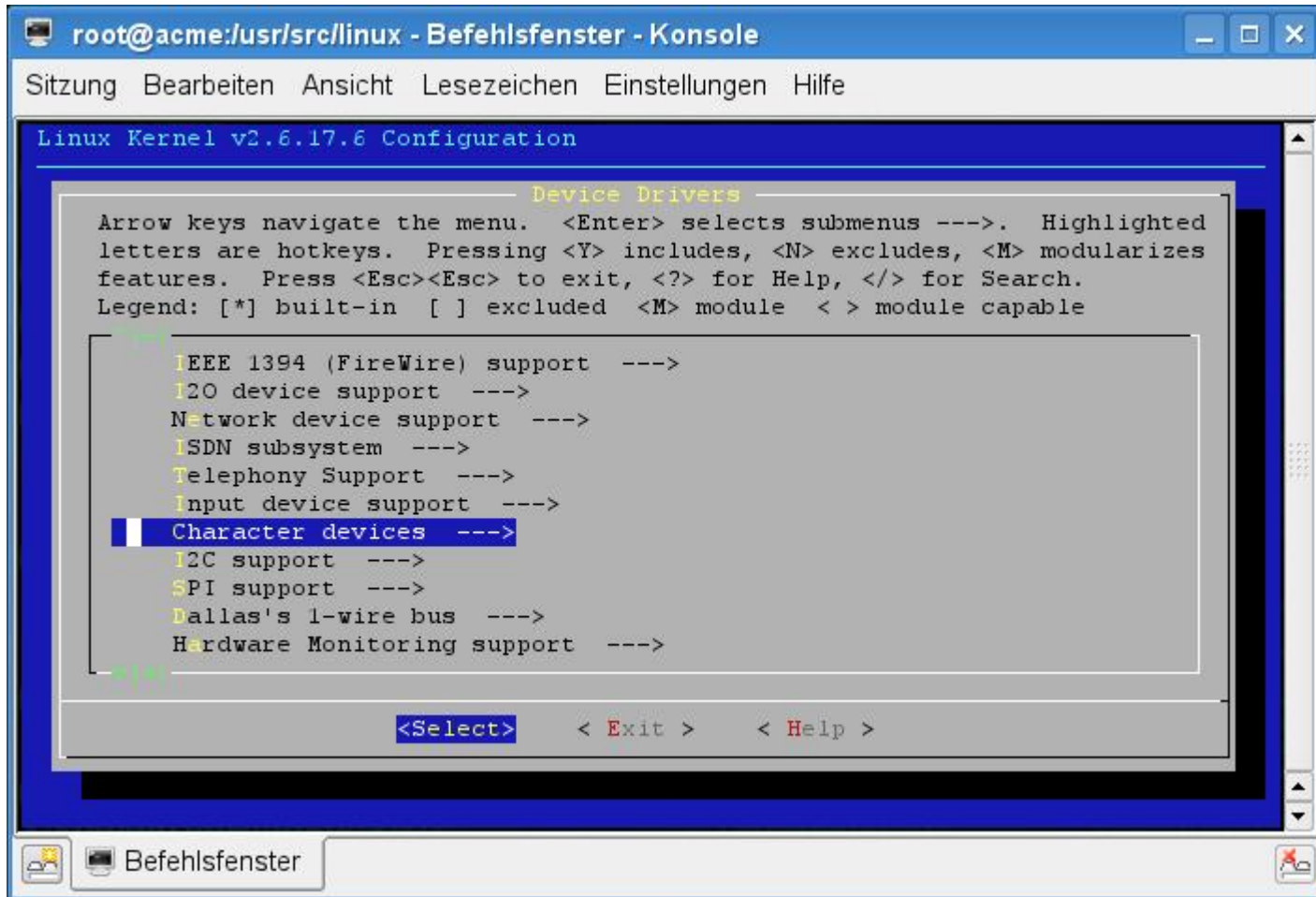
Linux Kernel v2.6.17.6 Configuration

----- Linux Kernel Configuration -----
Arrow keys navigate the menu. <Enter> selects submenus ---->. Highlighted
letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes
features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

Code maturity level options ---->
General setup ---->
Loadable module support ---->
Block layer ---->
Processor type and features ---->
Power management options (ACPI, APM) ---->
Bus options (PCI, PCMCIA, EISA, MCA, ISA) ---->
Executable file formats ---->
Networking ---->
Device Drivers ---->
File systems ---->

<Select> <Exit > <Help >
```

TPM device drivers (5)



```
root@acme:/usr/src/linux - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe

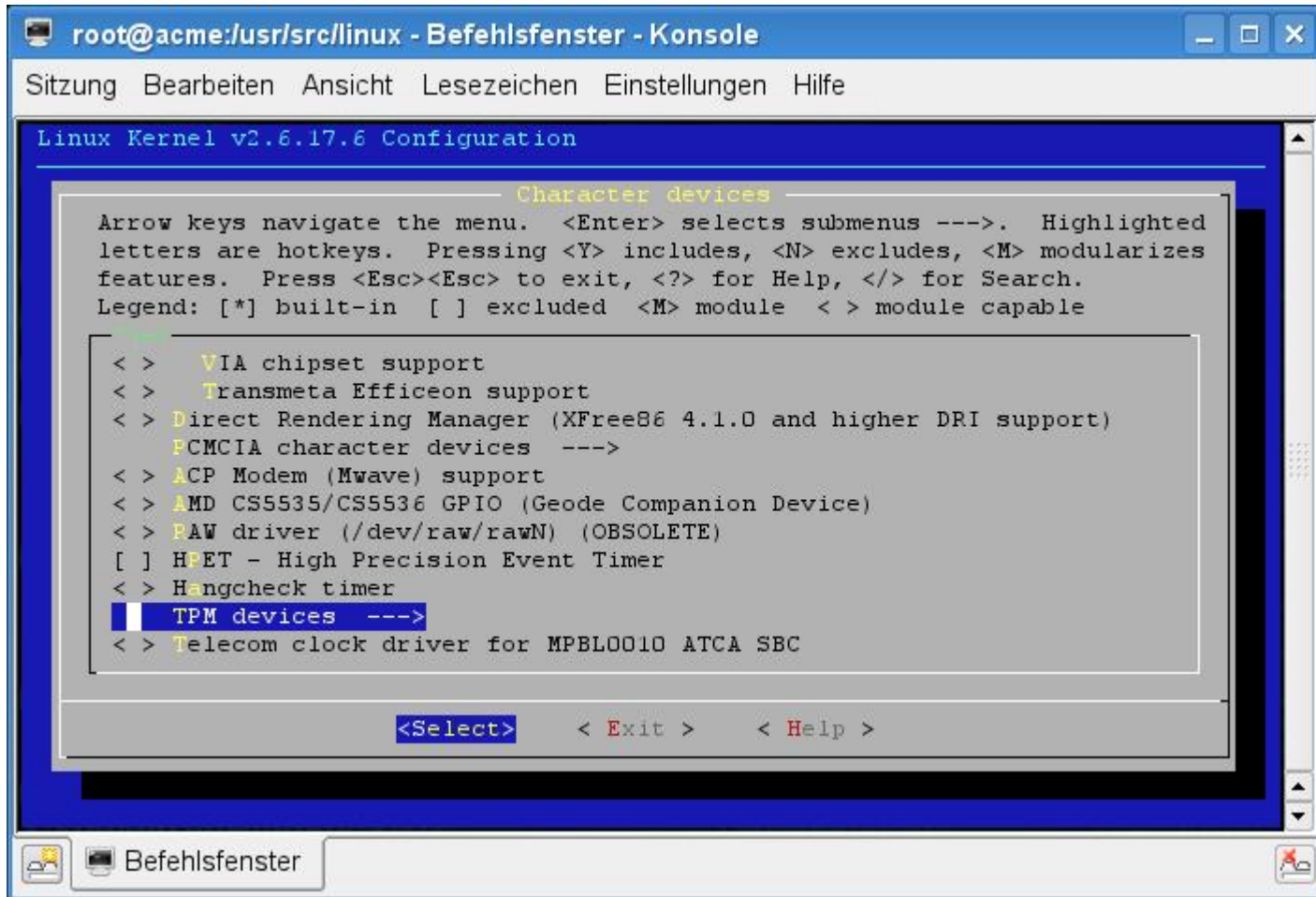
Linux Kernel v2.6.17.6 Configuration

----- Device Drivers -----
Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted
letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes
features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

IEEE 1394 (FireWire) support --->
I2O device support --->
Network device support --->
ISDN subsystem --->
Telephony Support --->
Input device support --->
Character devices --->
I2C support --->
SPI support --->
Dallas's 1-wire bus --->
Hardware Monitoring support --->

<Select> < Exit > < Help >
```

TPM device drivers (6)



```
root@acme:/usr/src/linux - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe

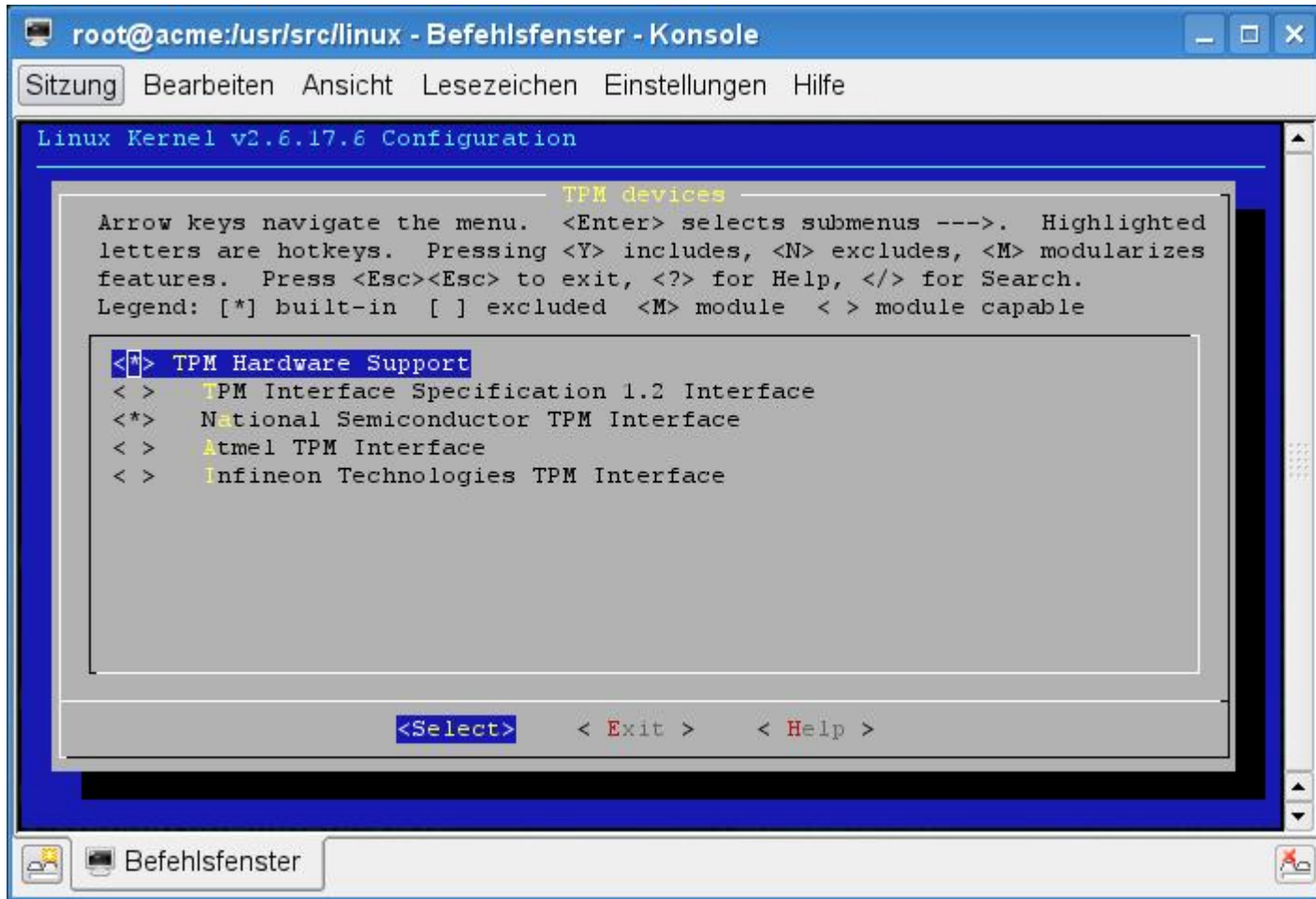
Linux Kernel v2.6.17.6 Configuration

----- Character devices -----
Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted
letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes
features. Press <Esc><Esc> to exit, <?> for Help, </> for Search.
Legend: [*] built-in [ ] excluded <M> module < > module capable

< > VIA chipset support
< > Transmeta Efficeon support
< > Direct Rendering Manager (XFree86 4.1.0 and higher DRI support)
PCMCIA character devices --->
< > ACP Modem (Mwave) support
< > AMD CS5535/CS5536 GPIO (Geode Companion Device)
< > PAW driver (/dev/raw/rawN) (OBSOLETE)
[ ] HPET - High Precision Event Timer
< > Hangcheck timer
[ ] TPM devices --->
< > Telecom clock driver for MPBL0010 ATCA SBC

<Select> < Exit > < Help >
```

TPM device drivers (7)



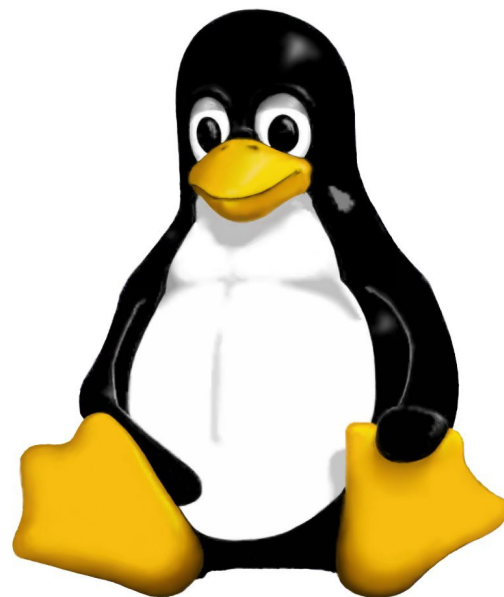
The screenshot shows a terminal window titled "root@acme:/usr/src/linux - Befehlsfenster - Konsole". The window displays the "Linux Kernel v2.6.17.6 Configuration" menu. The current menu is "TPM devices", which is highlighted in yellow. Below the title, there is a paragraph of instructions: "Arrow keys navigate the menu. <Enter> selects submenus --->. Highlighted letters are hotkeys. Pressing <Y> includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to exit, <?> for Help, </> for Search. Legend: [*] built-in [] excluded <M> module < > module capable". The menu items are:

- <Y> TPM Hardware Support
- < > TPM Interface Specification 1.2 Interface
- <*> National Semiconductor TPM Interface
- < > Atmel TPM Interface
- < > Infineon Technologies TPM Interface


At the bottom of the menu, there are three options: <Select>, < Exit >, and < Help >.

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)

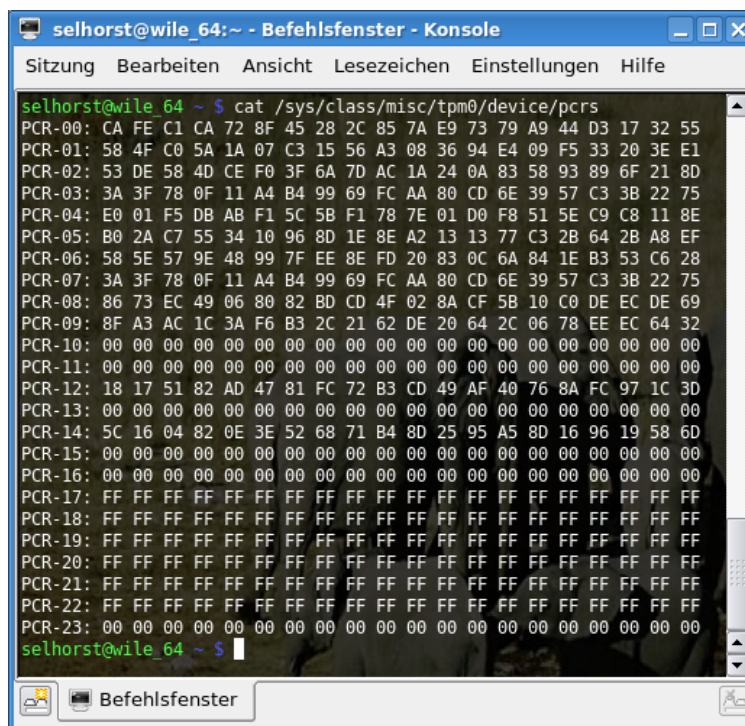
- Step 1: Open a Terminal / Konsole
click on this desktop icon 
- Step 2: Load the device driver
 - `sudo modprobe tpm_infineon`
- Step 3: Verify, that the TPM device driver has loaded successfully:
 - `lsmod | grep tpm`
 - `dmesg | grep tpm`
- Step 4: Verify the existence of the correct node-device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

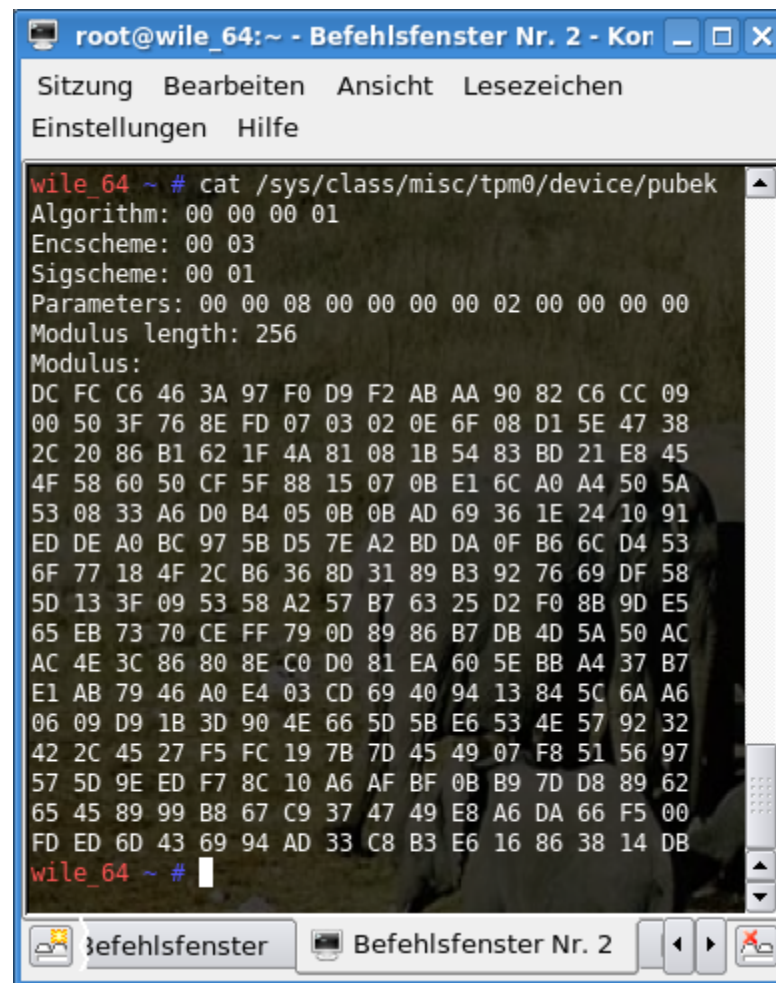


```
selhorst@wile_64: ~ - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe
selhorst@wile_64 ~ $ cat /sys/class/misc/tpm0/device/pcrs
PCR-00: CA FE C1 CA 72 8F 45 28 2C 85 7A E9 73 79 A9 44 D3 17 32 55
PCR-01: 58 4F C0 5A 1A 07 C3 15 56 A3 08 36 94 E4 09 F5 33 20 3E 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
PCR-18: 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
PCR-20: 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
PCR-22: 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 ~ $
```

- 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`



```
root@wile_64:~ - Befehlsfenster Nr. 2 - Kor
Sitzung Bearbeiten Ansicht Lesezeichen
Einstellungen Hilfe

wile_64 ~ # cat /sys/class/misc/tpm0/device/pubek
Algorithm: 00 00 00 01
Encscheme: 00 03
Sigscheme: 00 01
Parameters: 00 00 08 00 00 00 00 02 00 00 00 00
Modulus length: 256
Modulus:
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 3F 09 53 58 A2 57 B7 63 25 D2 F0 8B 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
06 09 D9 1B 3D 90 4E 66 5D 5B E6 53 4E 57 92 32
42 2C 45 27 F5 FC 19 7B 7D 45 49 07 F8 51 56 97
57 5D 9E ED F7 8C 10 A6 AF BF 0B B9 7D D8 89 62
65 45 89 99 B8 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
wile_64 ~ #
```

Content

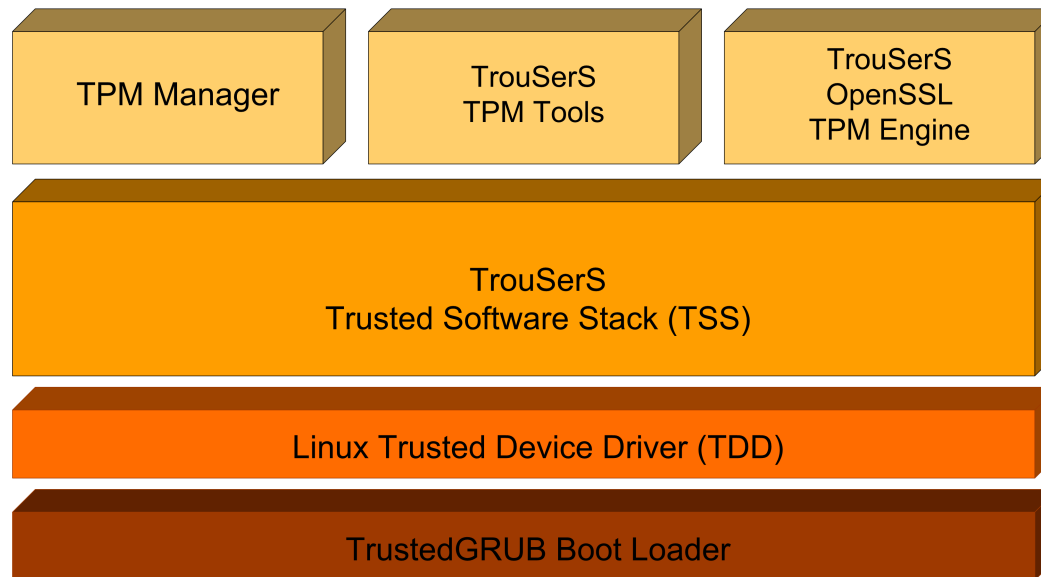
- Introduction to TPMs
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TPM open source software (1)

- 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



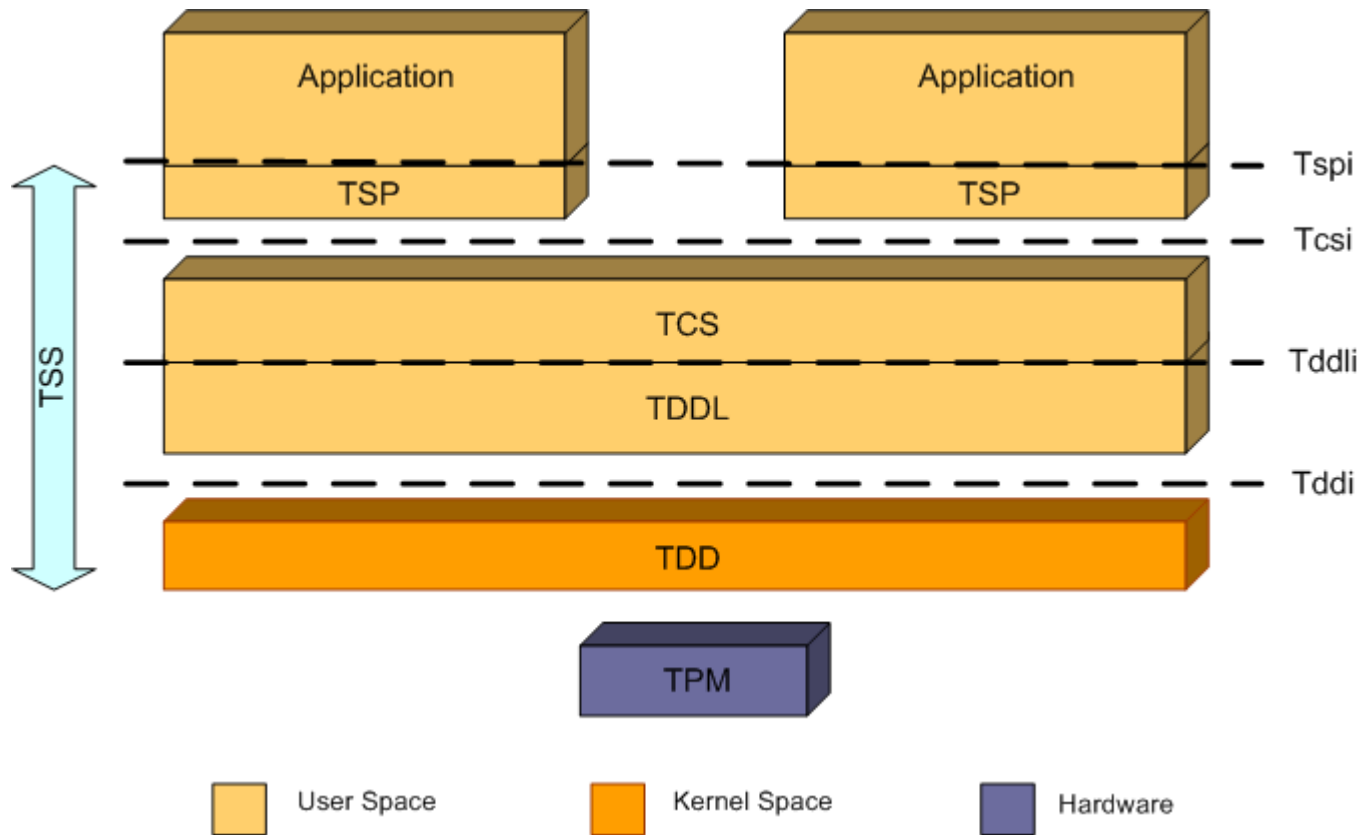
→ Chap. 5

Content

- Introduction to TPMs
- Platform Integration
- **Using the TPM with Linux**
 - TPM device drivers
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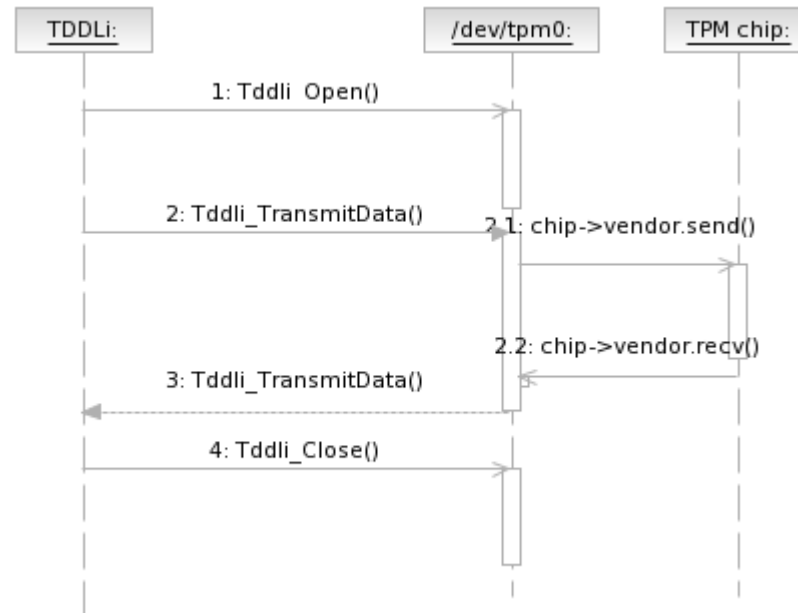
TPM open source software (3)

- 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:

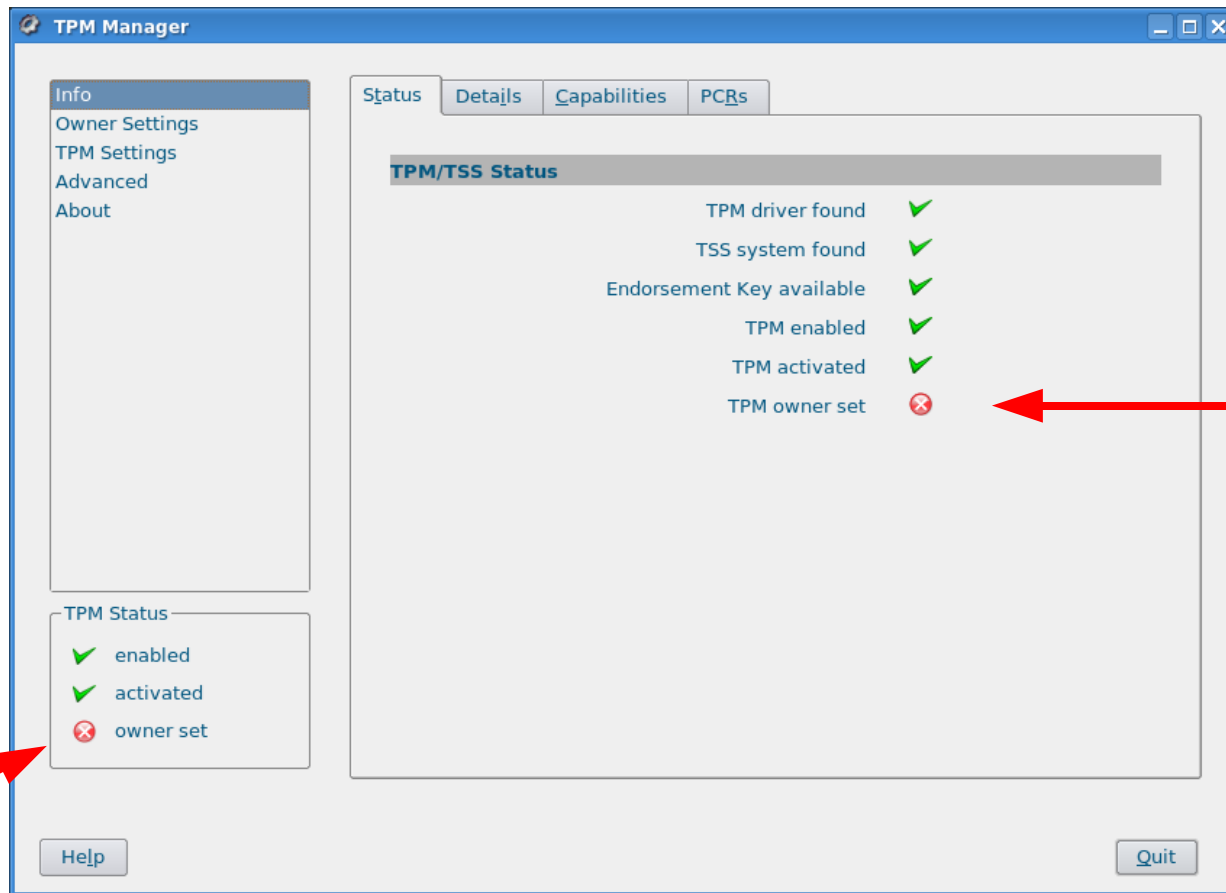
```
~$ tpmmanager
```

Content

- Introduction to TPMs
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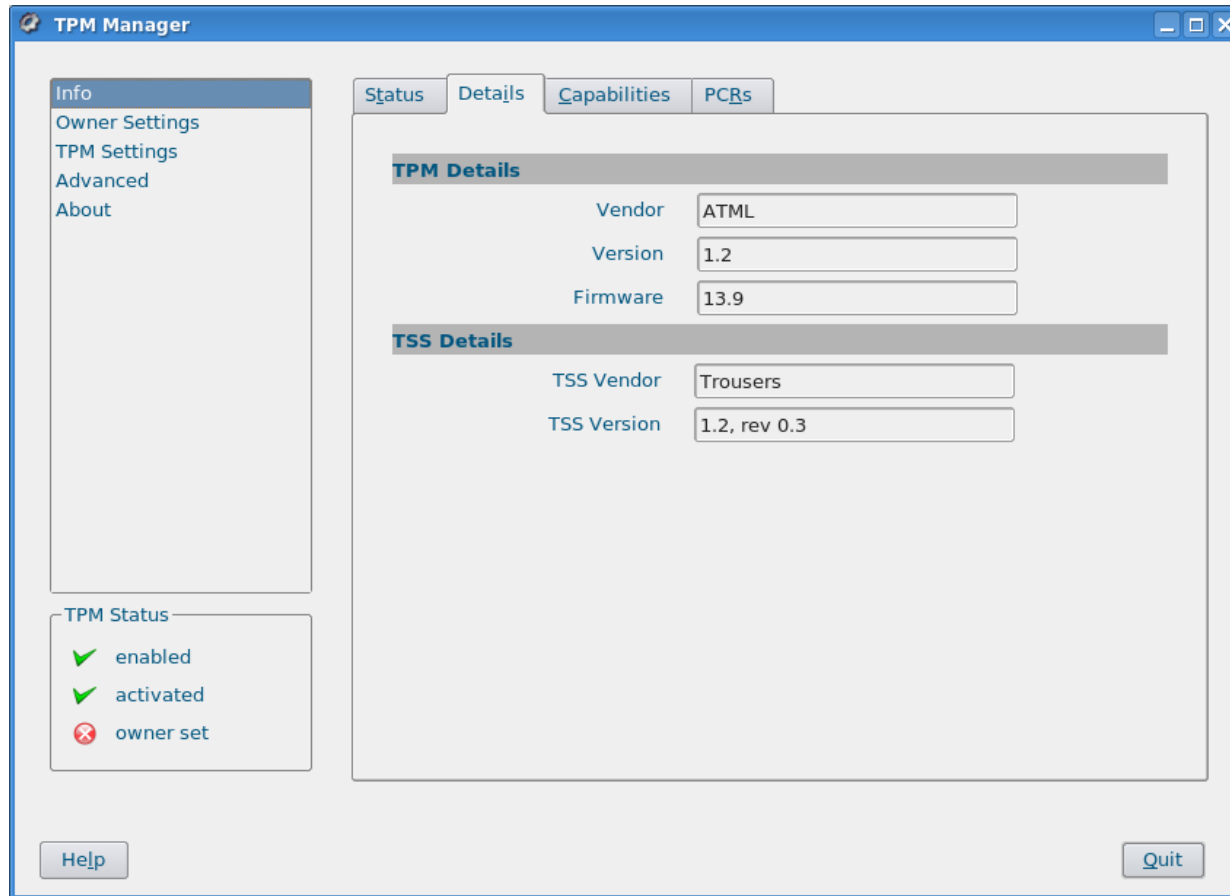
TPM open source software (6)

- TPM-Manager:



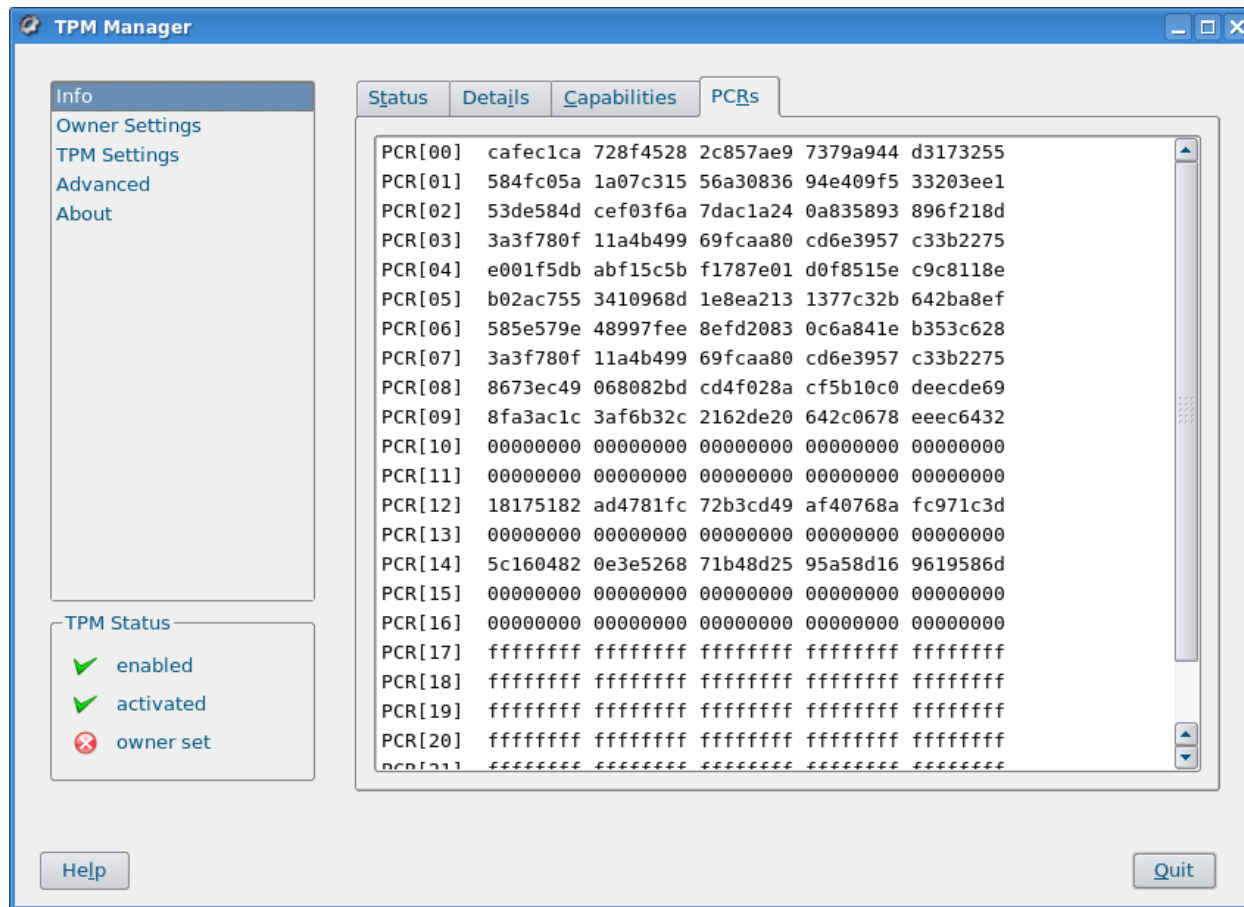
TPM open source software (7)

- TPM-Manager:



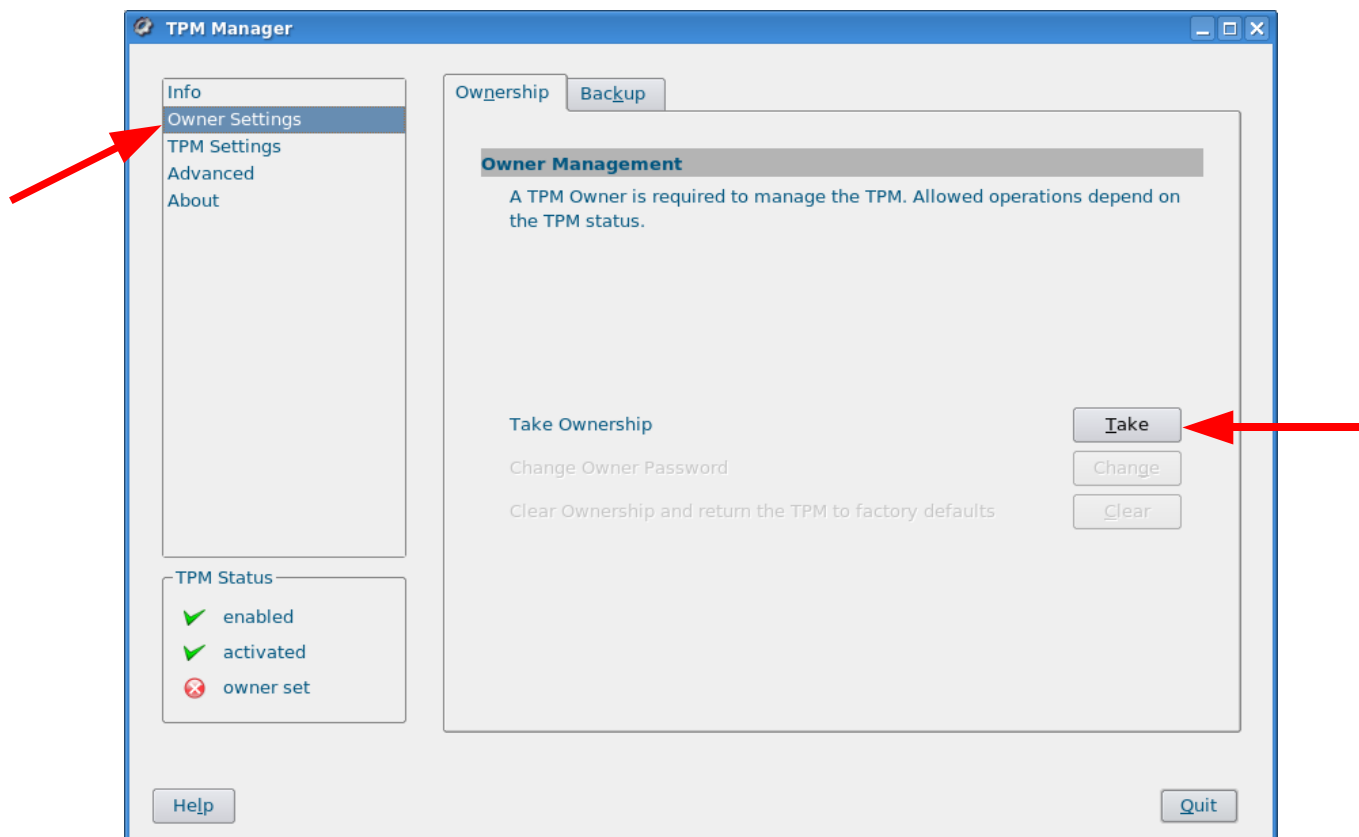
TPM open source software (8)

- TPM-Manager:



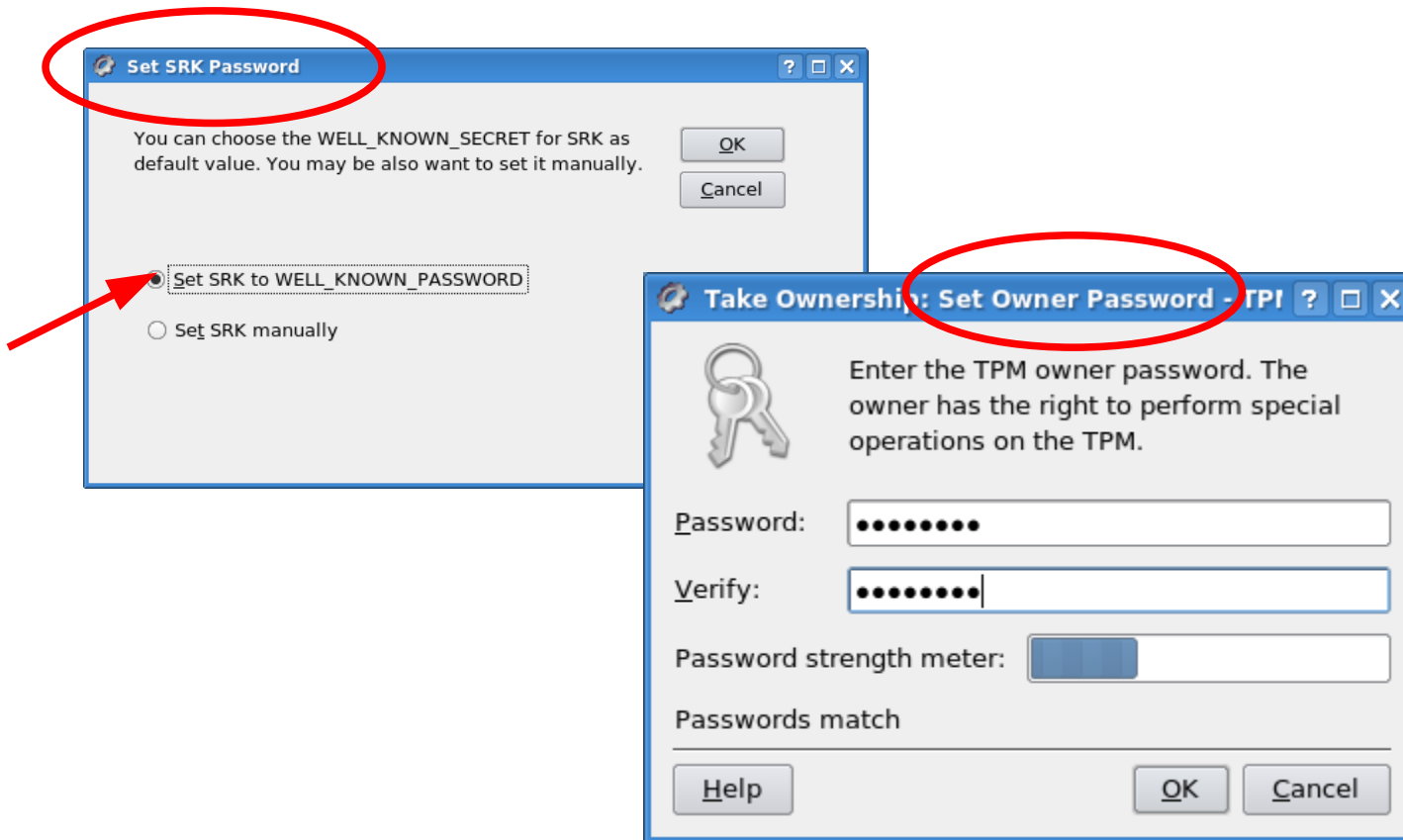
TPM open source software (9)

- Taking Ownership with the TPM-Manager:



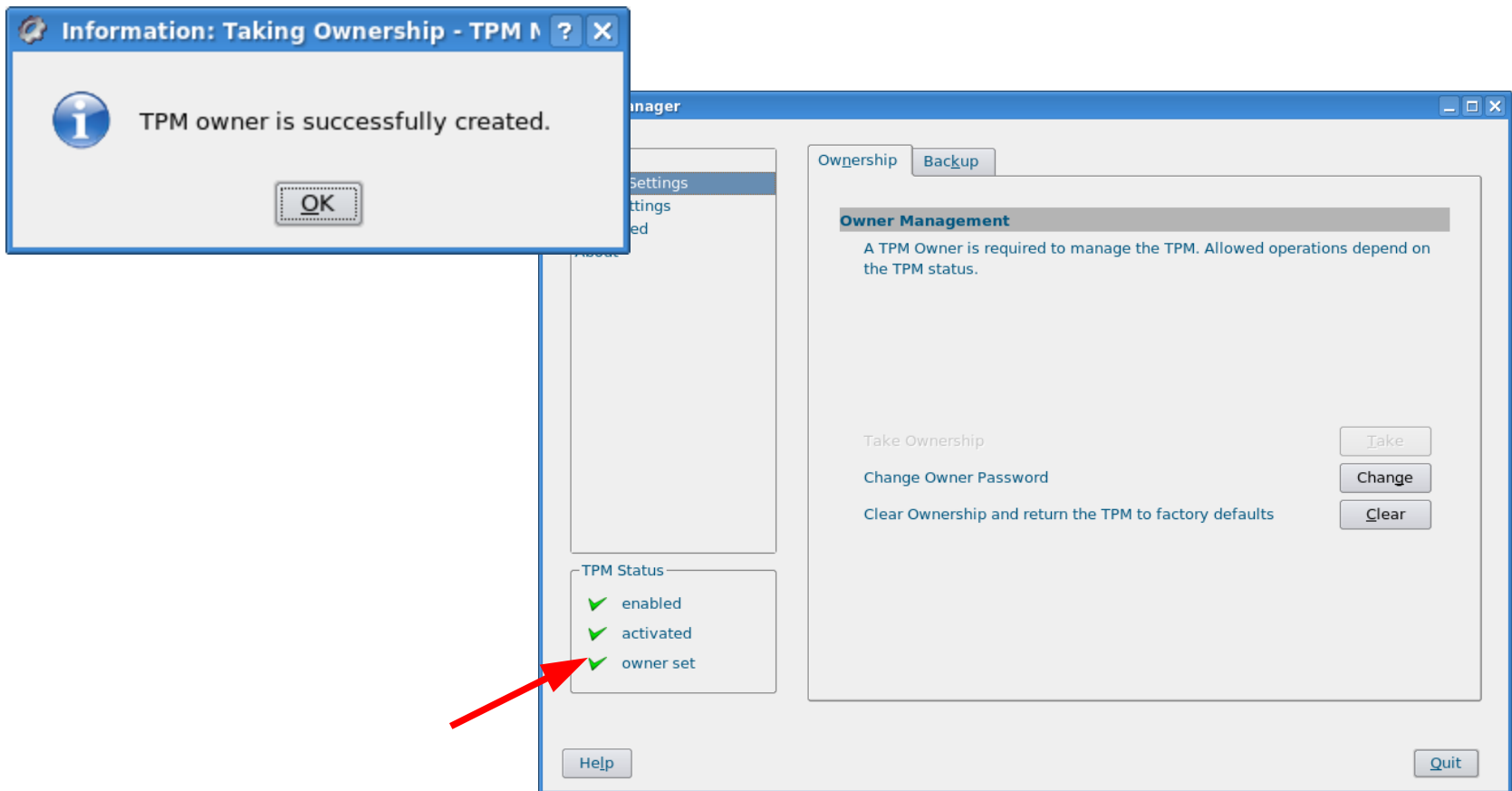
TPM open source software (10)

- Taking Ownership with the TPM-Manager:



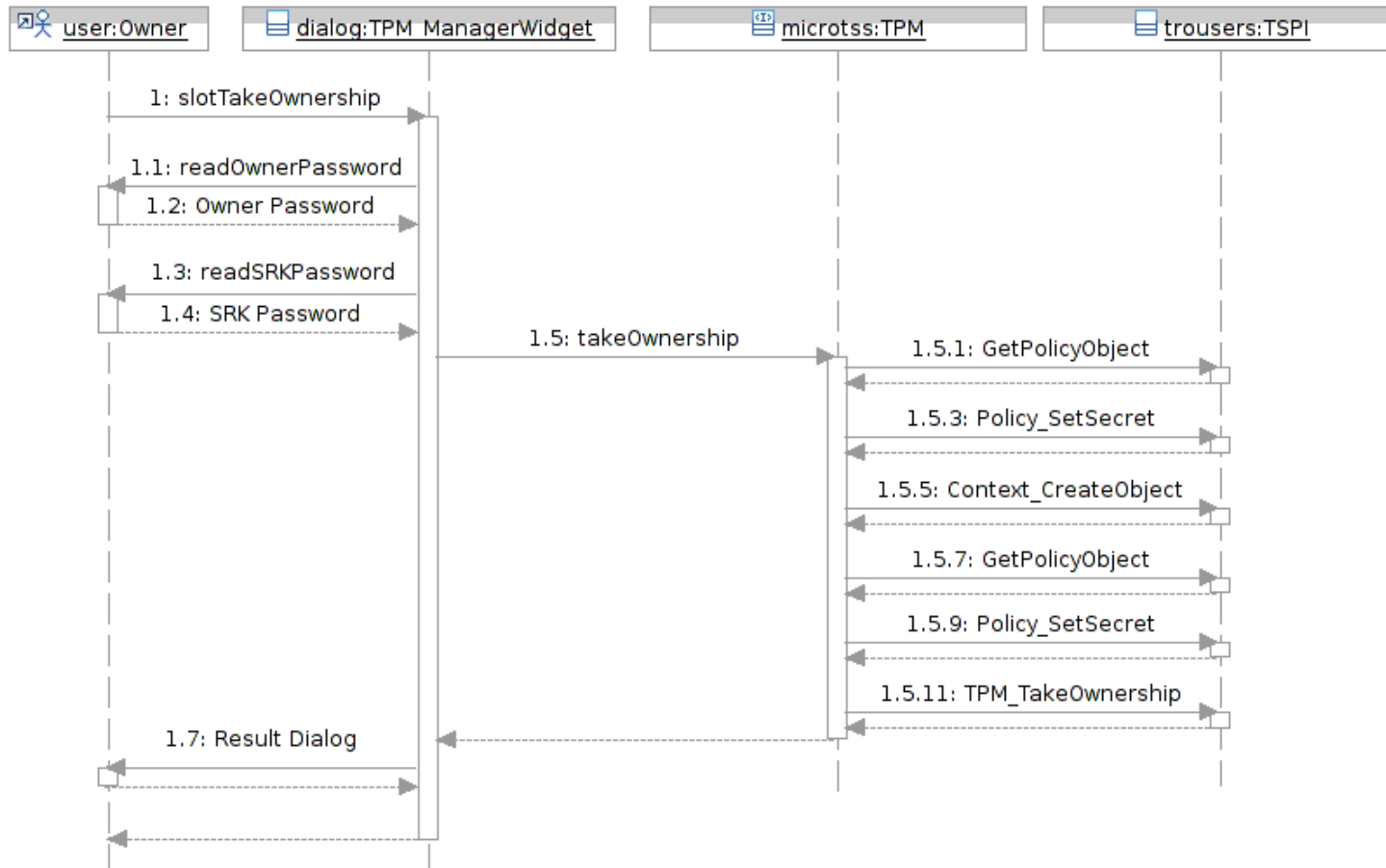
TPM open source software (11)

- Taking Ownership with the TPM-Manager:



TPM open source software (12)

■ Taking Ownership – TSS interaction:



Content

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

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		HMAC		Type	Name	Description
#	SZ	#	SZ			
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		HMAC		Type	Name	Description
#	SZ	#	SZ			
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
```

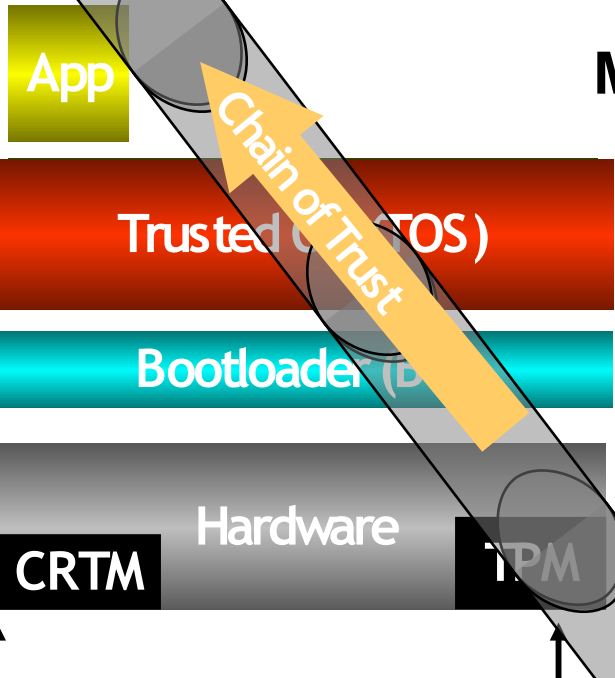
- make
- ./extend_pcr <some filename>

Content

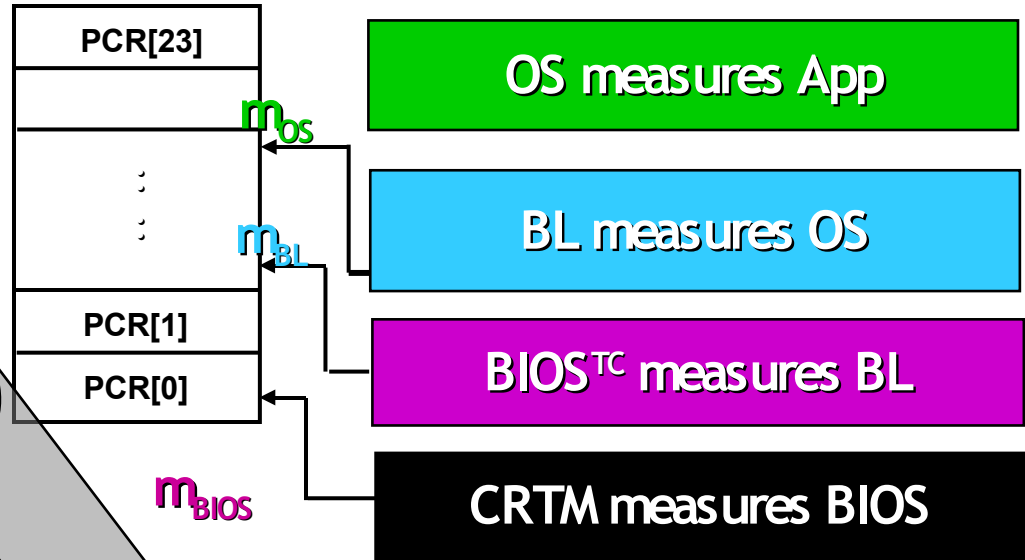
- Introduction to TPMs
- Platform Integration
- Using the TPM with Linux
- TPM commands
- **The Chain of Trust**

Instantiation based on TCG approach

Execution



Measurement



Trusted Components:

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

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:

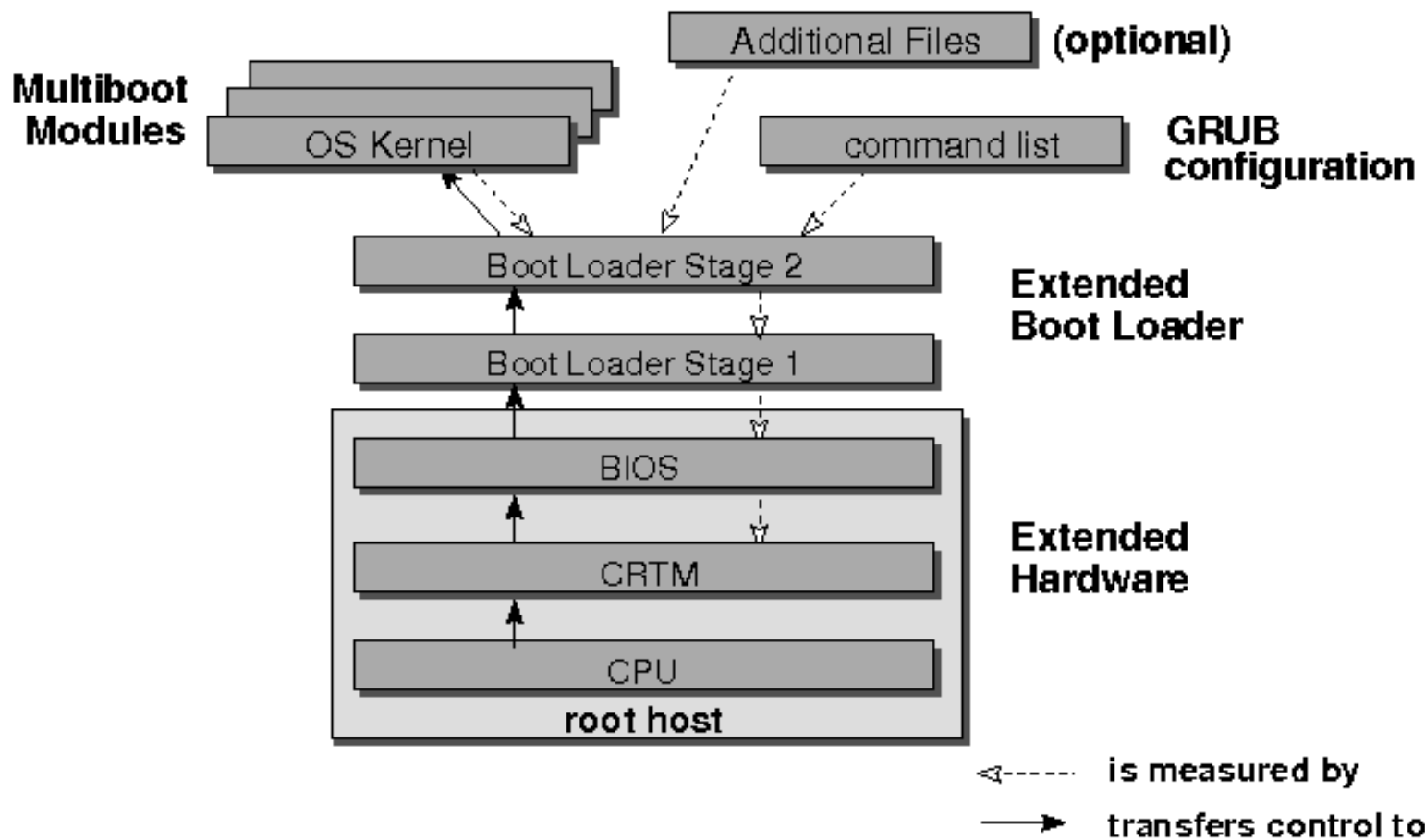
```

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



The Chain of Trust (6) - TrustedGRUB

Platform Configuration Registers (PCRs)

```

selhorst@wile_64:~ - Befehlsfenster - Konsole
Sitzung Bearbeiten Ansicht Lesezeichen Einstellungen Hilfe
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
PCR-11: 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
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
PCR-16: 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
PCR-18: 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
PCR-20: 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
PCR-22: 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
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:

$$\text{PCR}_{\text{new}} = \text{SHA1}(\text{PCR}_{\text{old}} \parallel \text{newValue})$$

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:

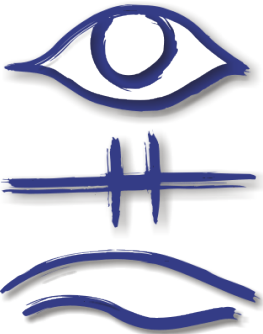
```
~ $ verify_pcr NULL /boot/vmlinuz
```

Result for PCR:

```
5c 16 04 82 0e 3e 52 68 71 b4  
8d 25 95 a5 8d 16 96 19 58 6d
```



Sirrix AG security technologies



**Thank you!
Any Questions?**

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