John Graham-Cumming's blog

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Cracking an old ZIP file to help open source the ANC's "Operation Vula" secret crypto code

It's not often that you find yourself staring at code that few people have ever seen, code that was an important part in bringing down the apartheid system in South Africa, and code that was used for secure communication using one-time pads smuggled into South Africa by a flight attendant on floppy disks. But I found myself doing that one morning recently after having helped decrypt a 30 year old PKZIP file whose password had long been forgotten.

Some time ago I became interested in the secure communications used by the ANC as part of Operation Vula in the late 1980s. Operation Vula was the infiltration of ANC leaders (and materiel) into South Africa to set up an underground network bringing together the various elements of ANC activism operating inside the country.

The operation needed secure communications to be successful and these were established using 8-bit computers, DTMF tones, acoustic couplers and a variety of other equipment for exchanging one-time pad encrypted messages using programs written in PowerBASIC.

I won't go into the detail of how this worked as Tim Jenkin, the person primarily responsible for the encryption system, has now open sourced the original code, and which can be found here. Tim's write up on the encryption system can be found here. I thoroughly recommend reading it for the details.

The code hadn't been open sourced before for one simple reason: on leaving the UK for South Africa in 1991 he had zipped up all the source code and set a password on it. In the intervening years he'd simply forgotten the password! So, when I emailed him to ask if it had been open sourced he replied:

> I still have the Vula source code but unfortunately most of it I can't access because when I left the UK in 1991 to return to South Africa, I zipped up all the files with a password. I was able to decode and extract one of the files but it was a very early version of the software. The rest I couldn't extract because I forgot the password. When I got back to SA there was no need to access the code. I thought I would never forget the password but when I tried to decode it a few years later, I couldn't remember it.
>
> If you could find out how to decode zipped files that would release the software, which I would be more than happy to share. I have made a few attempts to crack the code but so far have been unsuccessful.

I readily agreed and he sent me two files: `ALLBAS.ZIP` and `CODMAY93.ZIP`. These were both created with an early version of PKZIP and had passwords set on them. Luckily, there is a known plain text attack against the ZipCrypto scheme used in that era's ZIP format. And an open source implementation of the attack called `bkcrack`.

So, it was a "simple matter" of predicting 12 bytes of plain text at a known location inside the ZIP file. Here's a sample of what's inside the ZIP file:

```
$ bkcrack -L ALLBAS.ZIP | head -n 20

bkcrack 1.7.0 - 2024-05-26
Archive: ALLBAS.ZIP
Index Encryption Compression CRC32    Uncompressed  Packed size Name
----- ---------- ----------- -------- ------------ ------------ ----------------
    0 ZipCrypto  Shrink      b0f86b1d          163          117 A1PSW.BAS
```

```
     1 ZipCrypto  Shrink      8fa662d4          163            118 A2PSW.BAS
     2 ZipCrypto  Shrink      0c5a7295          163            119 A3PSW.BAS
     3 ZipCrypto  Shrink      49907f86          179            125 A4PSW.BAS
     4 ZipCrypto  Shrink      3d20eb7a          163            120 A5PSW.BAS
     5 ZipCrypto  Shrink      f8b558f0          136            128 BIOS.INC
     6 ZipCrypto  Implode     799074ed          377            278 CHKERR.INC
     7 ZipCrypto  Implode     c44ea0a5        17906           5401 CODSUBS.INC
     8 ZipCrypto  Implode     7bd7e23d        27287           8297 COMAID.BAS
     9 ZipCrypto  Implode     03dc63da         2109           1001 COMKEY.BAS
    10 ZipCrypto  Store       3500d320         2372           2384 CONFIG.TIM
    11 ZipCrypto  Shrink      35a85089          147            111 CONPSW.BAS
    12 ZipCrypto  Implode     55be75ce         2094            825 DOS.INC
    13 ZipCrypto  Shrink      3387d043          134            127 DOSVER.INC
    14 ZipCrypto  Implode     28a32efa         1304            535 DOSX.INC
    15 ZipCrypto  Implode     6578a66c         3196            966 EDDY.BAS
```

Tim had some unencrypted `.BAS` files lying around but they were different versions than those in the file and trying the `bkcrack` attack using them (after running them through original PKZIP in DOSBox) was unsuccessful and I decided to apply some brain power before attempting further attacks.

`ALLBAS.ZIP` contained a number of files that were uncompressed, because they were already binary and not worth compressing. These files are marked as `Store`:

```
$ bkcrack -L ALLBAS.ZIP | grep Store
    10 ZipCrypto  Store       3500d320         2372           2384 CONFIG.TIM
    23 ZipCrypto  Store       14a285ac            2             14 KEYCOD.EXE
    25 ZipCrypto  Store       d6343ce1         4767           4779 KEYONE.ZIP
    26 ZipCrypto  Store       650778b7         6523           6535 KEYTHREE.ZIP
    30 ZipCrypto  Store       12a711cd        58172          58184 OLDCOD.ZIP
    41 ZipCrypto  Store       00000000            0             12 TAPCOD.EXE
    44 ZipCrypto  Store       55000714        12716          12728 TECOD5.ZIP
    45 ZipCrypto  Store       f4f4366c         9230           9242 TECOD6.ZIP
```

Files that are `Store`'d are fruitful for plaintext prediction because they have not undergone compression and there's no need to have the original file to compress in order to obtain plaintext. Focussing on the ZIP files, since the ZIP files start with a PK header, seemed like a good place to find predictable plaintext at a known position. Here are the fields in the standard PK header at the very start of a ZIP file:

	0x0	0x1	0x2	0x3	0x4	0x5	0x6	0x7	0x8	0x9	0xA	0xB	0xC	0xD	0xE	0xF
0x00	P	K	0x3	0x4	Version		Flags		Method		Time		Date		CRC32	
0x10	CRC32		Compressed Size				Uncompressed Size				FN Size		Extra			
0x20	File name (variable length)															
0x30	Extra Field (variable length)															

A viable attack appeared to be to predict the name of the first file in the archive. If the file name was at least 8 characters (which seemed pretty easy since at least four characters were used for `.BAS`, `.INC` etc.) then at least 12 characters of plaintext would be available when the file name size (offset 0x1A, 0x1B) and the length of the extra field (which appeared to be 0x00, 0x00 in all the ZIPs Tim sent) was added.

In the worst case, it would be possible to bruteforce the potential names of files given that they all appear to be uppercase/number combinations with a maximum length of eight characters plus extension. But that turned out not to be necessary.

Happily, Tim had a different version of `OLDCOD.ZIP` (one of the ZIP files inside `ALLBAS.ZIP`) and was able to tell me that the first file in it was `COMKEY.BAS`. So, I whipped up a quick Perl program to create the necessary plaintext in that hope that the `OLDCOD.ZIP` inside `ALLBAS.ZIP` did start with `COMKEY.BAS`:

```
$ cat maken.pl
use strict;
use warnings;

my $outfile = "hexname-$$.txt";

while (<>) {
    chomp;
    my $bas = $_;
    print("$bas / $outfile\n");
    my $n = sprintf("%c\x00\x00\x00$bas",length($bas));
    open G, ">$outfile";
    print G $n;
    close G;
    system("bkcrack -C ALLBAS.ZIP -c OLDCOD.ZIP -p $outfile -o 26 -j 8");
}
```

23 minutes later `bkcrack` spit out the key to the `ALLBAS.ZIP` file and was able to decrypt it. The same key worked for `CODMAY93.ZIP` also.

```
$ time echo "COMKEY.BAS" | perl maken.pl
COMKEY.BAS / hexname-41227.txt
bkcrack 1.7.0 - 2024-05-26
[07:49:38] Z reduction using 6 bytes of known plaintext
100.0 % (6 / 6)
[07:49:38] Attack on 925073 Z values at index 33
Keys: 98e0f009 48a0b11a c70f8499
80.6 % (745571 / 925073)
Found a solution. Stopping.
You may resume the attack with the option: --continue-attack 745571
[18:13:49] Keys
98e0f009 48a0b11a c70f8499

real    23m4.371s
user    162m3.520s
sys     0m37.752s
```

`bkcrack` does the decryption once the key has been found:

```
$ bkcrack -C ALLBAS.ZIP -k 98e0f009 48a0b11a c70f8499 -D ALLBAS-DECRYPTED.ZIP
bkcrack 1.7.0 - 2024-05-26
[07:52:22] Writing decrypted archive ALLBAS-DECRYPTED.ZIP
100.0 % (81 / 81)
$ bkcrack -C CODMAY93.ZIP -k 98e0f009 48a0b11a c70f8499 -D CODMAY93-DECRYPTED.ZIP
bkcrack 1.7.0 - 2024-05-26
[07:58:31] Writing decrypted archive CODMAY93-DECRYPTED.ZIP
100.0 % (40 / 40)
```

And with that the long encrypted source code used to help set up secure communications for the ANC was available!

Had that failed I was going to attack one of the other ZIP files using the same attack (before resorting to bruteforceing file names). I'd guessed that `TECOD5.ZIP` was probably a ZIP of just the file `TECOD.BAS` (or maybe `TECOD5.BAS`) based on the compressed size of `TECOD.BAS` in `ALLBAS.ZIP`). Turns out I wouldn't have had to wait 23 minutes if I'd started there:

```
$ time echo "TECOD5.BAS" | perl maken.pl
TECOD5.BAS / hexname-41544.txt
bkcrack 1.7.0 - 2024-05-26
[18:14:51] Z reduction using 6 bytes of known plaintext
100.0 % (6 / 6)
[18:14:51] Attack on 880113 Z values at index 33
Keys: 98e0f009 48a0b11a c70f8499
2.4 % (20737 / 880113)
Found a solution. Stopping.
You may resume the attack with the option: --continue-attack 20737
[18:15:29] Keys
98e0f009 48a0b11a c70f8499

real    0m38.152s
user    4m35.318s
sys     0m0.897s
```

The known plaintext attack against ZipCrypto works quickly with the right plaintext. If you ever have to do something similar it's worth spending time thinking about the plaintext. In particular, files that are `Store`'d in the ZIP file are useful to examine since they are uncompressed and it may be easier to predict their contents (rather than having to find an original file and compress it to match what's stored in the ZIP).

Running the code

I compiled two of the programs and ran them using DOSBox. The first, RANDOM.BAS, was used to create disks of random numbers to be used as a one time pad, the other, TECOD.BAS, was used to encrypt and decrypt messages sent via email. The code I compiled and the generated executables can be found here.

Compilation is simply running the PowerBASIC compiler as follows:

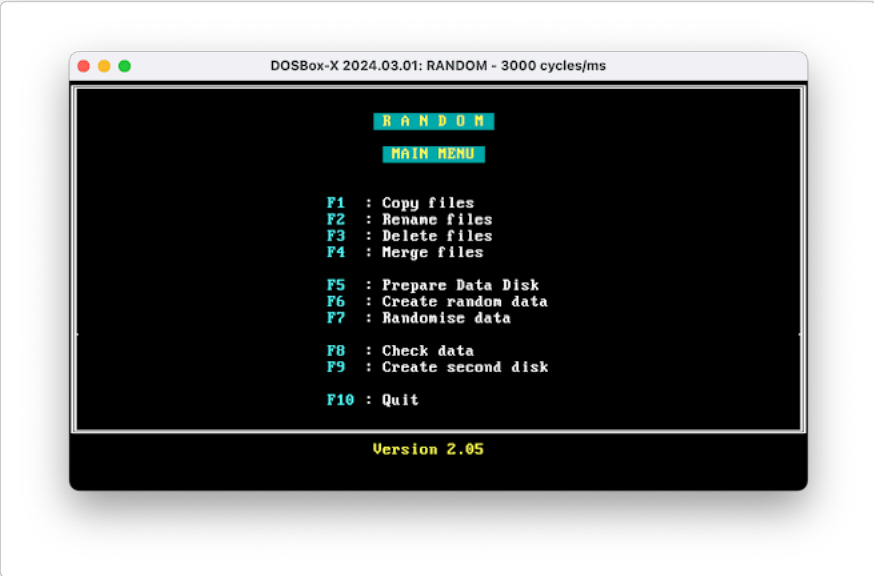
```
C:\>EXE\PBC TECOD.BAS
PowerBASIC Compiler Version 3.00b  Copyright (c) 1989-1993 by Robert S. Zale
Spectra Publishing, Sunnyvale, CA, USA
C:\TECOD.BAS
2575 statements, 2329 lines
Compile time: 00:12.0 Compilation speed: 12600 stmts/minute
45984 bytes code, 4880 bytes data, 2048 bytes stack
Segments(1): 46k

C:\>EXE\PBC RANDOM.BAS
PowerBASIC Compiler Version 3.00b  Copyright (c) 1989-1993 by Robert S. Zale
Spectra Publishing, Sunnyvale, CA, USA
C:\RANDOM.BAS
```

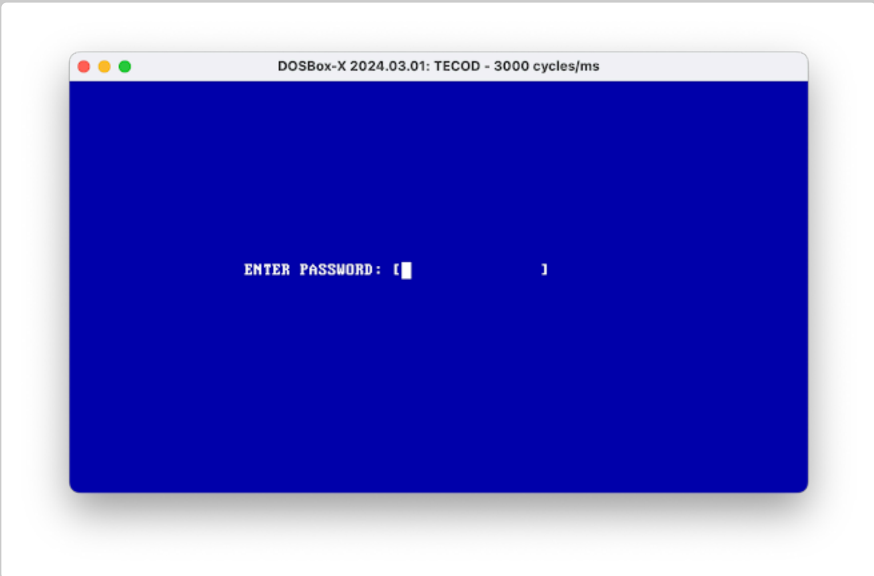
```
2194 statements, 1940 lines
Compile time: 00:10.1 Compilation speed: 12600 stmts/minute
33328 bytes code, 4704 bytes data, 3072 bytes stack
Segments(1): 34k

C:\>
```

The first step is to create random data on disk to be used as a one time pad. RANDOM.EXE uses three different randomness generating algorithms (one based on a random key you type in yourself).



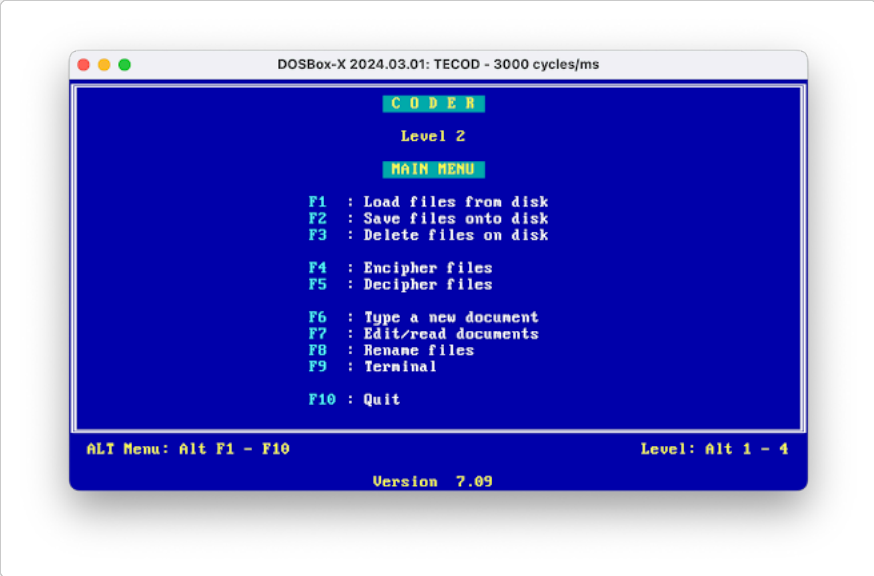
Encryption and decryption is done through TECOD.EXE which is password protected.



Although the password is embedded in the program and quite simple Tim Jenkin did obfuscate it as follows:

```
DIM PW$(PL)
PW$(9)=CHR$(66):PW$(4)=CHR$(66):PW$(1)=CHR$(84):PW$(5)=CHR$(79):PW$(2) = CHR$(73)
PW$(3)=CHR$(77):PW$(6)=CHR$(66):PW$(8)=CHR$(77):PW$(10)=CHR$(79):PW$(7)=CHR$(73)
```

In this particular version of the program that makes the password TIMBOBIMBO which when entered takes you to the main menu. Note that each version of these programs being sent to different members of the ANC had different passwords.



If you're interested in running these programs yourself, the manual is here.

Here are three short videos showing the creation of random data in RANDATA.1 for the key using RANDOM.EXE, followed by encrypting a message stored in PLAIN.TXT on a RAM disk (all crypto operations were meant to happen on a RAM disk) and turning it into PLAIN.BIN (and the reverse).

Creating random data to be used as an encryption key

Encrypting a file

Here the programs (TECOD.EXE/TECOD.CNF) are on a floppy disk in A:, the data disk (containing the key file created above) are in B: and there's a RAM disk on R:. To get this to work the RANDATA.1 file created in the step above needs to be renamed to SNUM.

Decrypting a file

Here the programs (TECOD.EXE/TECOD.CNF) are on a floppy disk in A:, the data disk (containing the key file created above) are in B: and there's a RAM disk on R:. The RANDATA.1 needs to be called RNUM on B:.

There are lots of interesting details of how these programs work that deserve another longer blog post when I have time. Or a detailed study by someone else. For example, the key material is destroyed after use, the RANDOM.EXE program has multiple ways of making randomness and code to check the distribution of the random bytes created. There's an emphasis on using the RAM disk for all cryptographic operations.

at September 07, 2024

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