Are Software Updates Useless Against Advanced Persistent Threats?

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Assurance and certification in secure Multi-party Open Software and Services (AssureMOSS) No single company does master its own national, in-house software. Software is mostly assembled from "the internet" and more than half come from Open Source Software repositories (some in Europe, most elsewhere). Security & privacy assurance, verification and certification techniques designed for large, slow and controlled updates, must now cope with small, continuous changes in weeks, happening in sub-components and decided by third party developers one did not even know they existed. AssureMOSS proposes to switch from process-based to artefact-based security evaluation by supporting all phases of the continuous software lifecycle (Design, Develop, Deploy, Evaluate and back) and their artefacts (Models, Source code, Container images, Services). The key idea is to support mechanisms for lightweigth and scalable screenings applicable automatically to the entire population of software components by Machine intelligent identification of security issues, Sound analysis and verification of changes, Business insight by risk analysis and security evaluation. This approach supports fast-paced development of better software by a new notion: continuous (re)certification. The project will generate also benchmark datasets with thousands of vulnerabilities. AssureMOSS: **Open Source Software: Designed Everywhere, Secured in Europe**. More information at https://assuremoss.eu.

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Are Software Updates Useless Against Advanced Persistent Threats?

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A dilemma worth Shakespeare's Hamlet is increasingly haunting companies and security researchers: "to update or not to update, this is the question". From the perspective of recommended common practices by software vendors the answer is unambiguous: you should keep your software up-to-date [7]. But is common sense always good sense? We argue it is not.

Last year on a CACM's column Poul-Henning Kamp [4] argued that these industry best practices do not seem to work and a more radical reform is needed. In the same year, on the IEEE S&P magazine Massacci, Trent and Peisert reminds us that the SolarWinds attack was funneled by an update [5] and a second choral piece this year [6] tells us that the recent protestware attacks are also channeled through updates.

What is badly wrong here is that updates are hardly classified as either functionality or security updates or both. They are bundled together for the convenience of the software vendor [5]. For example, the WhatsApp update v2.19.51, while patching a critical security vulnerability exploited by the NSO Group, summarized the update with the following note: "You can now see stickers in full size when you long press a notification". One might concede, without believing it, that conflating together functionality and security updates is done to make it more difficult to identify the vulnerable code.

Yet, this lack of transparency is not going to help. Organizations can only blindly accept the "black-box" cumulative update that will force them to install all updates ignored so far, or equally blindly ignore the popup. As Trent Jager said: damned if you patch, damned if you do not.

Still, updates might be normally good and might turn to be unwise only in the high-profile cases that hit the media.

We investigated whether this is the case in the context of Advanced Persistent Threats (APTs) [2], 'la creme de la creme' of the attacker ecosystem. APTs are sophisticated actors that deliberately and persistently target specific individuals and companies with a strategic motivation (from sabotage to financial gain). In this scenario, only an 'all hands on deck' defense seems appropriate and keeping your software up-to-date seems the bare, and likely not even sufficient, minimum.

Starting from 'Operation Aurora' the security community increasingly released public information about APTs campaigns via blogs and technical reports. Unfortunately, the information is fragmented over different sources, each using different taxonomies to track adversaries. So, we collected data about more than 350 APT campaigns performed by 86 APTs in more than 10 years from more than 500 resources (and, by the way, the data is open source[1]).

From this wealth of data, we can try to understand if these Threats called APTs really deserve the acronym they got.

A as Advanced: In most cases, APTs do not even exploit a software vulnerability. Figure 1 shows the attack vectors employed in the campaigns. More than half of them do not employ any software vulnerability. APTs rely on spearphishing attacks via email and social networks to obtain the initial footprint in the network.

[1] https://doi.org/10.5281/zenodo.6514817

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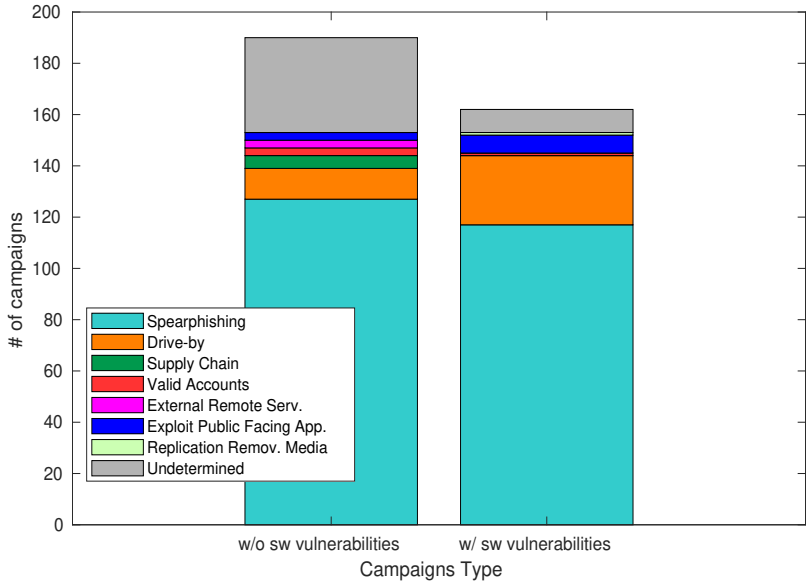


More than half of the campaigns do not exploit software vulnerabilities but extensively rely on spearphishing to get initial access.

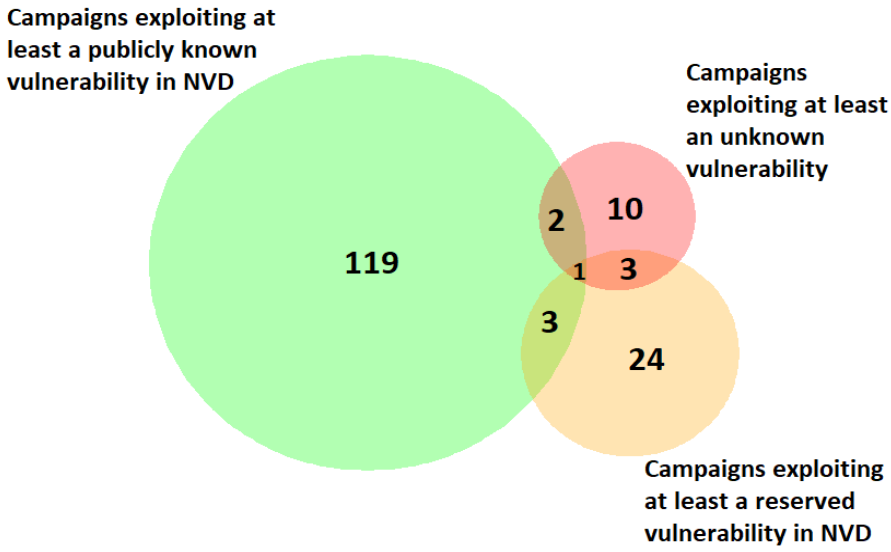
Fig. 1. Attack vector campaigns and software vulnerabilities

Whether your software is up to date or not makes no difference in at least 50% of the cases, as software vulnerabilities are not the main attack vector. The 'all-powerful' attacker supporters could argue that we are a victim of survival bias as we used data of security attacks that have been eventually discovered. As Richard Clayton said at the Workshop on Economics of Information Security on 2017, "we don't always know if are measuring dim attackers getting caught rather than smart attackers getting through". This is a valid point if we consider a single point in time. Eventually, even smart attackers will be, if not caught, at least spotted. For example, we can hardly say that the Stuxnet and Solarwinds attacks were performed by unskilled attackers. Still, they have eventually been in the news. Thus, a decade of reports can give a reasonably accurate view of the attacker ecosystem.

So let's zoom in on the half of the attacks where software vulnerabilities did play some role.

P as Persistent. When APTs exploit software vulnerabilities, they often exploit vulnerabilities of which the vendor is aware and for which a patch is available. The 0-days exploits are not the norm. Figure 2 summarizes the number of campaigns that exploited known or 0-day software vulnerabilities. The 77% of the campaigns in our dataset rely on at least a vulnerability that was previously published on NVD at the time of the attack.

This finding seems pretty solid evidence that software updates are actually useful. If APTs are exploiting software vulnerabilities that are known, and for which an update exists, then staying always on the edge of the newest Microsoft Office or Adobe Acrobat version should be enough to prevent the exploitation. Unfortunately, raw uninterpreted statistics of hindsight can be misleading.



Most of the campaigns exploited at least one vulnerability after reservation and publication by NVD. Only a few launched attacks exploiting unknown vulnerabilities that were neither reserved nor published by NVD.

Fig. 2. Classification of APT Campaigns.

The first problem with "Keep your software updated to the newest version" is that the pace of updates is often very close to a Denial of Service against IT administrators with no improvement in security [1]. Many updates are *not* security updates and updates tend to break other functionalities. Huang et al. [3] in a paper aptly entitle up-to-crash found out that many seemingly innocuous updates of vulnerable Android libraries might crash the dependent application with up to 50% chances. Toss a coin, if head is up, software is down.

So we decided to investigate the potential effectiveness of keeping the software up-to-date for 5 widely used software products in the decade under study (Office, Acrobat Reader, Air, JRE, and Flash Player) from three major software companies (Adobe, Microsoft, and Oracle) for the Windows O.S. with different strategies.

The *Ideal* strategy represents the unrealistic scenario of staying on the edge of the wave and update the software as soon as a new release is available. The software vendor's speed is the only limiting factor.

The *Industry* strategy is a more realistic representation of the dutiful organizations that follow the industry best practices and apply each new update with some delay between the release of an update and its installation to perform regression testing. Delay ranges from one week to several months.

A more relaxed *Reactive* strategy just focuses on updating when a CVE for a software vulnerability is published in a database of vulnerabilities like NVD.

T as Threat. As we (now) know when the attack took place with some approximation (i.e almost all reports only indicate the month of the attack), we can calculate the Agresti-Coull 95% confidence interval that doing an update *at that time* was actually useful or not. In other words, we can calculate the conditional probability that you would have updated on the same month, or updated the next month when the update became available and still have succumbed to an APT - if they ever decided to target you.

Figure 3 shows the range in which the probability of being compromised lies for the different strategies considering a one-month delay for the *Industry* and *Reactive* strategies to perform regression testing. When the intervals overlap it means the two strategies are not statistically distinguishable. That is a vey bad news for the IT administrators that struggled to keep pace of the updates.

In Figure 3 we observe that either an enterprise applies at light speed lots of updates (the *Ideal* strategy) or the risk of being compromised once you have to wait to perform regression testing for all new releases of the software (*Industry* strategy) is the same as if you just wait for a CVE to come out (*Reactive* strategy) but the latter saves you from a lot of useless updates. Furthermore, even if we are keeping our system up to date at light speed, we also need to be lucky to not jeopardize our effort. Indeed, if we consider the worst-case scenario of a strategy, where APTs are slightly faster to exploit than enterprises to patch (i.e. on the same month), the probability of being compromised significantly overlaps with the more relaxed strategy of waiting for a CVE to be published.

All-speedful defenders are as unrealistic as all-powerful attackers, thus it seems perfectly rational to save time and money and only rush to update for *disclosed* vulnerabilities and before that do nothing. That is what most company seems to do and get lambasted for.

What is the answer? If the "keep your systems up to date" best practice is only effective when the enterprises spend most of their resources on fixing and maintaining their suppliers' software instead of servicing their own customers, then why do we stick with this recommendation?

This is a best practice that can be included in the "security theatre" [8], measures that provide minimal benefits and are not worth the cost.

As Kamp points out in the mentioned CACM columns [4] this industry 'best practice' allows cyber-insurance companies to reject requests for coverage. Most importantly, it allows software companies to shift liability towards their "lazy" users. For the software vendors (starting from the big four), this best practice is the most desirable because releasing an update that "improves" an unknown feature of a product is much easier than implementing it as a secure application with mechanisms like automatic network segmentation and escalation and execution confinement [5] and without unnecessary frills.

We agree with Poul-Henning Kamp, it is a jolly good time to introduce the 'right to not update' [5] and return the liability of defective software building to the software builders and not to the software users [4].

Dwellers of the U.S. Capitol or Brussel's Berlaymont should take notice of the copy of the old Code of Hammurabi reported in Table 1 along with its counterpart in the IT reign. It is for the future to align its liability laws to the past.

To summarize: If "how to have more security?" is the question, software updates are not the answer.

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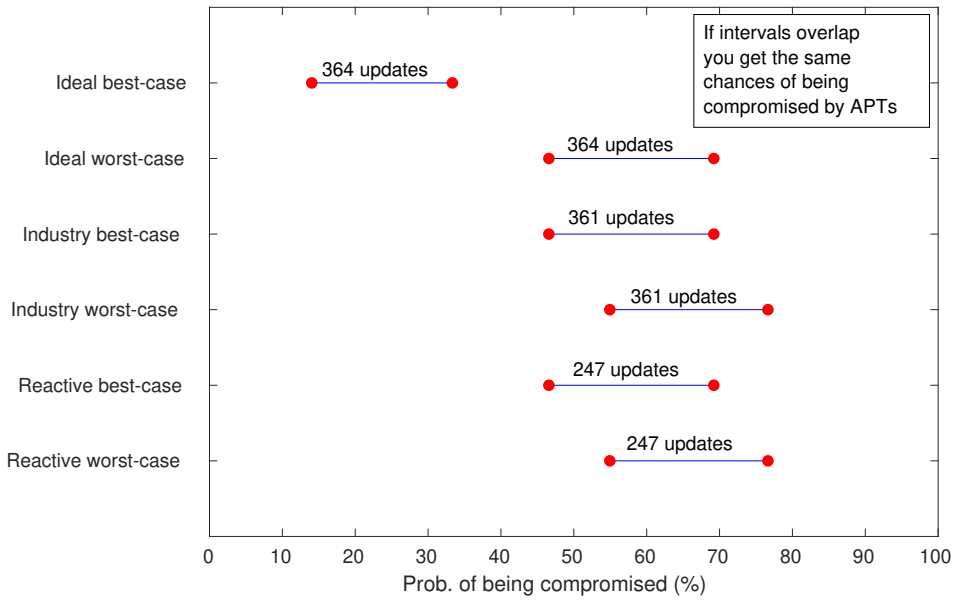

In the best-case scenario, updates are deployed *before* exploitation if they overlap on the same date. In this case, either an enterprise updates immediately or the risk of being compromised by updating only when a CVE is published is the same as always updating to the newest version. In the worst-case scenario, updates are deployed *after* exploitation if they overlap on the same date. In this case, even if an enterprise updates immediately there is considerable overlap in the probability of being compromised with more relaxed approaches

Fig. 3. Agresti-Coull confidence interval of the probability of being compromised for update strategies (one month delay for *Industry* and *Reactive* strategies)

Table 1. The IT Code vs the Building Code of Hammurabi

What Happens	Code of Hammurabi (ca. 1780 BC)	Code of IT Industry (2022 AD)
If a [builder] did not construct properly the house for a fellow [...] and a wall fell	that builder shall make that wall sound using his own silver	that builder will suggest another house he built and that fellow should pay to move one's goods to the other house.
If the house fell and it ruins goods	[the builder] shall make compensation for all that has been ruined	*unthinkable*
if the builder wants change the walls or close a window of the house after the sale	*unthinkable*	the fellow shall adapt its living to the new house at one's own expenses

[3] J. Huang, N. Borges, S. Bugiel, and M. Backes. 2019. Up-To-Crash: Evaluating Third-Party Library Updatability on Android. In *IEEE European Symposium on Security and Privacy*.
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[5] Fabio Massacci, Trent Jaeger, and Sean Peisert. 2021. Solarwinds and the challenges of patching: Can we ever stop dancing with the devil? *IEEE Security & Privacy* 19, 2 (2021).
[6] F. Massacci, A. Sabetta, J. Mirkovic, T. Murray, H. Okhravi, M. Mannan, A. Rocha, E. Bodden, and D. E. Geer. 2022. "Free" as in Freedom to Protest? *IEEE Security & Privacy* 20, 5 (2022).
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