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// Secure by Design
IoT Security Checklist
Is it secure?

If you want to develop a robust, trustworthy connected product, that will be secure during its total product lifecycle, then you need to ensure compliance with the UK's Secure by Design standards.

The UK is taking 'decisive action' on IoT security and is taking a staged approach to enshrining the standards in law. The UK's consumer connectable product security regime will come into effect on 29 April 2024. Businesses which are involved in the supply chains of these products will need to be compliant with the new regime by this date.

The UK has also been leading efforts to create international alignment and as such has been working with other territories to align standards in the US (NIST) and EU (ETSI).

Our checklist is by no means intended to be an exhaustive list, but instead a guide that gives you a set of questions to ask at every stage in the product development journey, perhaps throwing light on some important areas you may not have thought of yet. These questions are guided by four key aspects of attack surface analysis: deterrence, prevention, detection, correction and counter measures.

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Discover our companion guide: **How to future-proof your IoT device** - achieving 'Secure by Design' for IoT and connected devices.

13 Principles in the UK Government's 'Secure by Design' Code of Practice

// Secure by Design - Guidance at a glance

SbD1 – No default passwords
All IoT device passwords must be unique and not resettable to any universal factory default value.

SbD2 – Implement a vulnerability disclosure policy
Provide a public point of contact so that security researchers and others are able to report issues.

SbD3 – Keep software updated
Software components in internet-connected devices should be securely updateable.

SbD4 – Securely store credentials and security-sensitive data
Any credentials must be stored securely within services and on devices. Hardcoded credentials in device software are not acceptable.

SbD5 – Communicate securely
Security-sensitive data, including any remote management and control, should be encrypted in transit.

SbD6 – Minimise exposed attack surfaces
All devices and services should operate on the 'principle of least privilege'.

SbD7 – Ensure software integrity
Software on IoT devices must be verified using secure boot mechanisms.

SbD8 – Ensure personal data is protected
Where devices and/ or services process personal data they should do so in accordance with data protection law.

SbD9 – Make systems resilient to outages
Resilience must be built in to IoT services where required by the usage or other relying systems.

SbD10 – Monitor system telemetry data
If telemetry data is collected from IoT devices and services, such as usage and measurement data, it should be monitored for security anomalies.

SbD11 – Make it easy for consumers to delete personal data
Devices and services should be configured such that personal data can easily be removed or deleted by the consumer.

SbD12 – Make installation and maintenance of devices easy
Installation and maintenance of IoT devices should employ minimal steps and should follow security best practice on usability.

SbD13 – Validate Input data
Data input via user interfaces and transferred via application programming interfaces (APIs) or between networks must be validated.

Access full definitions and details of the UK Government's Secure by Design principles here

// Your IoT product development and security checklist

1 // The Beginning - Requirements Analysis

Your analysis needs to capture all security requirements. But, there is invariably a dependency between the proposed user experience and security to support that experience. This leads to questions such as:

- [ ] What is the minimum viable solution that supports the envisaged user experience?
- [ ] How does departing from that minimum viable solution impact upon the requirements for security?
- [ ] What are the impacts of: installation, software updates, password entry, deletion of personal data and other security measures on the user experience?
- [ ] For each solution the security implementation should be proportionate to the Secure by Design guidance. Example - have the security requirements of the complete system been specified considering the extent to which data and communications need protecting? Has the impact on the user experience been considered for different security scenarios?
- [ ] Could the user experience be varied such that significant security requirements can be removed? Example – by not communicating or storing sensitive information, the requirement to protect it can be removed.
- [ ] What are the impacts of negative security cases? Example – what is the user experience of failure to boot or if a breach is detected?
- [ ] Is the transfer of ownership a specified use case? What is the proposed approach to transferring ownership and resetting security?
- [ ] What happens when devices are decommissioned and disconnected from the service? Offboarding and onboarding are key events in the user experience and have wide security implications.
- [ ] Has GDPR been adequately covered in the requirements analysis and security considerations?
- [ ] Are software updates forced, optional or deferrable? For different territories it may be necessary to consider who owns the product, interruption to usage and negative use cases of the update failing or taking an extended time due to communication issues?
- [ ] For the required functionality, how do the system components (silicon, radio, cloud, operating system, apps) communicate and what are their attack surfaces?
- [ ] What level of resilience is required? Example – what level of functionality is required if the product is disconnected?
- [ ] What telemetry is required to provide the required functionality and support security monitoring?
- [ ] What mandatory security standards apply to the solution (such as NIST or codes of practice) and have they been included in the requirements analysis?
- [ ] Has cloning of components been considered? What are the operational impacts of clone protection?
- [ ] Is secure key or certificate revocation required?
- [ ] Have the requirements for security patching all of the components in the system been considered? Depending upon the number and types of components there may be a complex set of patching updates that need to be managed.

2 // Before Manufacture - Attack Surface Analysis

IoT systems often consist of multiple components with the ability to add and remove components. This introduces flexibility but also provides multiple attack points that can be exploited.
An attack surface analysis considers each of these components in isolation, considering their individual security requirements but also considering what happens as the system scales. Such an analysis leads to the questions below which can be addressed using threat analysis tools:

Threat Analysis Tools

Prevent: How can the implementation use standard security tools such as encryption, signing or one-time programming to prevent the threat?

Deter: What can be done to deter the threat?

Correct: How will the system respond and recover in order to correct the threat. Are countermeasures such as revocation or security renewal needed?

Detect: How will the threat be detected in an appropriate timescale?

STRIDE is a model often used to identify and categorise computer security threats.

Threat	Desired property
Spoofing	Authenticity
Tampering	Integrity
Repudiation	Non-repudiability
Information disclosure	Confidentiality
Denial of Service	Availability
Elevation of Privilege	Authorisation

Source: a model of threats developed by Praerit Garg and Loren Kohnfelder at Microsoft

- [ ] What physical and wireless network interfaces does my solution expose to the outside world?
- [ ] What hardware interfaces does my solution expose to the outside world?
- [ ] Have interfaces for servicing and refurbishing the product or any interface used during product development been considered? Examples – Jtag, serial and internal interfaces. Could these interfaces be secured?
- [ ] What are the protocols used for data in transit? Example – is HTTPS used?
- [ ] What storage is used for data at rest? Is this storage secure?
- [ ] What types of users and applications can talk to my solution? Is rights-based access implemented and if so what are the security requirements?
- [ ] How can I secure all of the interfaces for each user in a manner proportionate to my security requirements?
- [ ] What are the requirements for secure updates?
- [ ] What data am I expecting at each interface? What happens when that data is inconsistent with expectations?
- [ ] Removing complexity reduces risk. Have I removed all libraries and drivers that are not required by my solution from the operating system?
- [ ] Does my solution require a secure trusted execution environment to isolate data and process code that is security critical?
- [ ] Is my system of such value that a Differential Power Analysis (DPA) attack is a concern for my product? Again, proportionate security requires consideration of the value of data and operation.
- [ ] Is complete disabling of the product required if tampering is detected? Example – the case is opened.

3 // Before Manufacture - Design and Development

Interaction between the attack surface analysis and the design and development process uncovers realities around the proportionality of security requirements. As the implications of the security requirements become apparent, decisions about what data is communicated, how it is stored and how the system operates will be clearer. This leads to questions such as:

- [ ] Has the design and development process introduced new interfaces, protocols, or other attack surfaces? If so, repeat the attack surface analysis from stage 2 for the new attack surfaces.
- [ ] If the design includes any secure keys or certificates, what device security features will you need to provide an appropriate hardware root of trust?
- [ ] What operating system features does your design require? Example - should some processes have reduced privileges? Do you use memory protection, memory obfuscation or a trusted execution environment?
- [ ] What are the hardware implications of the secure boot requirements? Example – do you need a ROM boot load or an immutable flash participation?
- [ ] What are the hardware implications of the software update mechanism? Example - do you use double banked flash and what are the performance implications of writing to flash while maintaining normal operation?
- [ ] How do I use my attack surface analysis to harden my operating system and code?
- [ ] How many encryption keys do I need to secure various aspects of my design?
- [ ] What hardware and hardware design measures best suit my security needs? Example - consideration could include device selection based on security features, package selection such as BGAs, buried tracks, test point coverage and blind vias.
- [ ] How will I generate and distribute keys?
- [ ] Where is personal data stored in the system and is it secure?
- [ ] What happens when each of my interfaces disconnects – can my system deal with communication outages?
- [ ] Are my in-field devices uniquely identifiable and how is this identifier secured?
- [ ] What affordances need to be put in place to allow engineers to efficiently develop hardware, software and associated systems during development?
- [ ] Do development affordances create additional attack surfaces?
- [ ] Do the libraries and other software components used have any known, current vulnerabilities?
- [ ] What are the known vulnerabilities associated with selected protocols and encryption algorithms?
- [ ] Will the selected key lengths offer sufficient protection over the lifetime of the product?
- [ ] Is impaired network testing needed?
- [ ] Is penetration testing needed?
- [ ] Is fuzzy testing and negative use case testing required?

4 // Before Manufacture - Production Planning

When considering system components, it's important to consider what is known about them.
For most products, the majority of software is third-party code in the form of libraries and the operating system. This is significant and can be an easily overlooked source of vulnerabilities. For components developed for the solution, the interaction between the attack surface analysis and the design and development process gives confidence that the system is well characterised. This is not the case for 'bought-in' components. Bought-in components must go through an attack surface analysis but this is likely to be dependent upon information from the supplier. So, the production/buying stage leads to questions such as:

- [ ] Am I building all of the solution or integrating some bought in components? If buying in components the attack surface analysis of stage 1 must be undertaken. This will require access to vulnerability disclosure from the component's supplier.
- [ ] If I am manufacturing, where am I manufacturing and how can I distribute keys to the site securely?
- [ ] How do I audit the manufacturing process to ensure security? How do I prevent cloning?
- [ ] Can keys be eavesdropped or manipulated during production and how will we detect this?
- [ ] How will keys, certificates and unique IDs be programmed into the product?
- [ ] When onboarding the device with the cloud system how will keys and certificates be provisioned?
- [ ] What system integration and testing is required before I deploy?
- [ ] How will I check the correct programming of keys?
- [ ] Can production perform appropriate testing with security in place?
- [ ] How is production rework handled?

5 // During Manufacture - Secure Key Generation

Depending upon the security requirements of your system there may be one or more secure keys required.
This leads to questions such as:

- [ ] What elements of my system need symmetric keys?
- [ ] Are any of the keys shared between endpoints?
- [ ] Where am I generating the keys?
- [ ] Do I need and do I have a True Random Number Generator?
- [ ] What controls on people and equipment are needed during the key generation and distribution processes? Example – access to buildings, equipment and audit trails.
- [ ] How are the keys securely transferred to the endpoints?
- [ ] Are the keys stored securely at the endpoints, including at the key generator, if needed?
- [ ] Do keys expire and how are they updated?
- [ ] How will backup keys for disaster recovery and business continuity be managed?

6 // Operation & Updates - Consumer Device in the Field

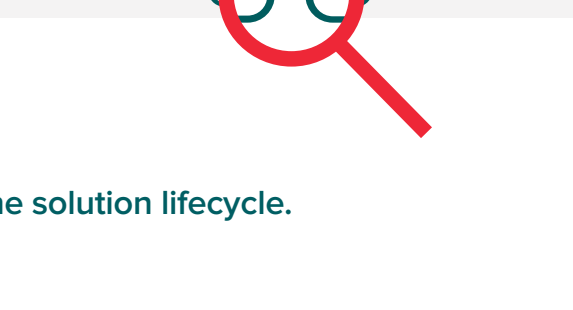
Once deployed there are a myriad of requirements for managing and communicating with the device in the field.
In field management is an essential aspect of maintaining your device security this leads to considerations such as:

- [ ] How do I record and track public key of unique IDs used in production?
- [ ] How will sensitive data be wiped when the product is decommissioned?
- [ ] Have the wider security implications of integrating the device into a system been considered?
- [ ] What other systems am I interoperating with and what are the security implications?
- [ ] Does the device management system support clone detection and have mechanisms to monitor telemetry for unusual behaviour?
- [ ] Are the operational and device management systems in place and appropriately secure for onboarding, status tracking, version control, ownership tracking, offboarding and device health?

7 // Operation & Updates - OTA Updates and Data Communication

Once deployed, the components in the field will begin communicating back and providing the designed system solution.
At this stage, communications between components and the ability to update them remotely becomes critical. Over-the-air updates (OTA) require management and occur within the secure environment implemented. This requires consideration of questions such as:

- [ ] What are my requirements for over the air updates and can my software be updated securely?
- [ ] What OTA software am I using and how secure is it?
- [ ] Can credentials and security sensitive data be stored securely?
- [ ] What feedback and success measurements are possible following update?
- [ ] How is failing hardware recorded?
- [ ] Does the security of the OTA and device management solution effectively lock you to that provider?



// Total Life Cycle - Maintaining Trust

Over time the in-field solution must be kept healthy; moving from fire-and-forget to management of the solution lifecycle.
This ongoing responsibility has many facets and includes questions such as:

- [ ] Who monitors for emergent threats and provides fixes?
- [ ] Who monitors for security patches in my open-source and third-party code, and applies them?
- [ ] Do your suppliers have vulnerability disclosure policies that ensure you are notified of any vulnerabilities in their products and are they enforcing such a policy with their suppliers?
- [ ] Have countermeasures and remedial actions been considered for likely breaches?
- [ ] Who detects breaches and deploys countermeasures?
- [ ] Who writes and manages the vulnerability disclosure policy, and do you have a procedure in place to respond to disclosures?
- [ ] Are security researchers able to easily and securely notify you about vulnerabilities?
- [ ] How will you communicate vulnerabilities to your customer base?
- [ ] How will you actively manage software updates?
- [ ] How will you repair secure devices in the field?
- [ ] What legal position should you take in regard to any breach?
- [ ] Do consumers of your products and services know how to contact you if they find a security vulnerability?
- [ ] Are you able to quantify the amount of cost/effort expected to process and resolve reported vulnerabilities in a timely manner?
- [ ] Do you have an internal procedure defined if a vulnerability is discovered, which also may affect the wider industry?

Consult Red is a technology development partner helping clients deliver connected devices and systems, supporting them through the entire product development journey.

We've helped to develop hundreds of connected devices and systems - from concept to millions of deployed products - for some of the world's largest brands. We know the journey and can help you manage risk and get to market faster.

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