It is essential to protect IT systems against security threats. An example would be the control of aircraft, which uses an internal network that passengers can access. It is important to ensure that malicious code on passenger equipment cannot endanger flight safety.

Information flow control is an important approach to the protection of systems against such threats. Notable examples include tainting analyses in languages such as Javascript, and program transformations on cryptographic algorithms to avoid information leakage through running time. A wide variety of techniques, including type systems and reference monitors, have been proposed in the context of programming languages and process calculi, to enforce such properties. The most widely used definitions of information flow security are noninterference-like properties.

For concurrent systems where processes communicate with each other to accomplish computational tasks, fine-grained security policies can be formulated by distinguishing between whether communication can happen, and what is communicated. As the first contribution of this PhD thesis, we formulate a noninterference-like property that takes all combinations of sensitivity levels for “whether” and “what” into consideration, emphasizing the importance of the integrity case where the former is more sensitive than the latter. This case captures the effect of Message Authentication Codes (MAC) and the consequence of Denial of Service (DoS) attacks. It is also proved that the property degenerates to a classical one when the two dimensions are intentionally blurred.

As the second contribution, we focus on the “what” dimension and further allow the flow policy to vary under different contents stored and communicated. This is the area of content-dependent (or conditional) information flow, which has recently been studied for sequential programs. We generalize the use and enforcement of content-dependent flow policies to concurrent, communicating processes. A security type system is developed, incorporating a Hoare logic component that provides approximations of the memory contents at different program points. Most proofs for the theoretical results on content-dependency are performed in the Coq proof assistant.

The third contribution of this thesis is the obtainment of compositionality results that support modular security analyses of computer systems.

A multiplexer pattern that separates sensitive and non-sensitive network traffic is used as a running example. Whether communications can happen is easily influenced by an attacker — attacking one of the incoming channels would suffice. In any case, the two data paths are still differentiable by the sensitivity levels of what is communicated. In case the destinations of messages are determined by their tagging, content-dependent policies are able to convey the correlation between the sensitivity level of a message and its tagging, and our Hoare-logic equipped type system allows a modular analysis of the overall system.