



The machinery that powers many of our interactions today—Web search, social networking, email, video entertaining, shopping, game playing—is made of the tiniest and the most massive computers. The tiny part is your handheld device, likely a smartphone that is over ten times faster than the 1970s' iconic Cray-1 supercomputer, even if much less stylish. As powerful as it is, your handheld's main task is simply to interact with you and your environment, while the bulk of your computing needs are implemented as Web services that run on building-sized computing system that we call Warehouse-Scale Computers (WSCs).

WSCs emerged early this century as an evolution of the more traditional data center, a co-location shared hosting facility (or colo) where a provider makes a business out of delivering floor space, physical security, power, cooling and networking connectivity for businesses to operate their computing servers from. Unlike the colo, a WSC is typically owned and operated by a single business like Google, can scale beyond tens of thousands of servers, and is operated as one gigantic computing system. Perhaps most importantly, WSC designers—software, hardware, mechanical, electrical, environmental, thermal and civil engineers—don't erect a building and then populate it with computing gear but instead design one massive computer whose chassis happens to look like a warehouse.

Cost and energy efficiency dictate every aspect of a WSC architecture. While a traditional colo may have a boutique shop window sophistication to their physical design, aiming to visually impress

the discriminating enterprise executive, WSC designs instead feature the spartan simplicity of the factory floor. Inside the WSC, ambient temperature remains at a balmy 25° to reduce cooling costs. Since computers are like smart space heaters, transforming electricity into heat with YouTube cat videos and web search results as byproducts, removing heat efficiently from the building is key. In another example of function over form, Google servers lack the blinking panels and front-panel displays common in standard servers. In fact, they lack front panels altogether, these being just another obstacle to efficient cooling.

In the context of this issue, it is impossible not to reflect on how WSCs best represent the place where Computer Architecture meets Vitruvius' ancient art. The term Computer Architecture was coined in 1962 by famed IBM computer designer Frederick Brooks as "the art of determining the needs of the user of a structure and then designing to meet those needs as effectively as possible within economic and technological constraints". One of Google's newest WSC facilities in Hamina, Finland, is perhaps the perfect physical realization of that meeting of disciplines, being housed in an old paper mill, originally designed by Alvar Aalto. Firmness, commodity, delight, and truly massive computing.