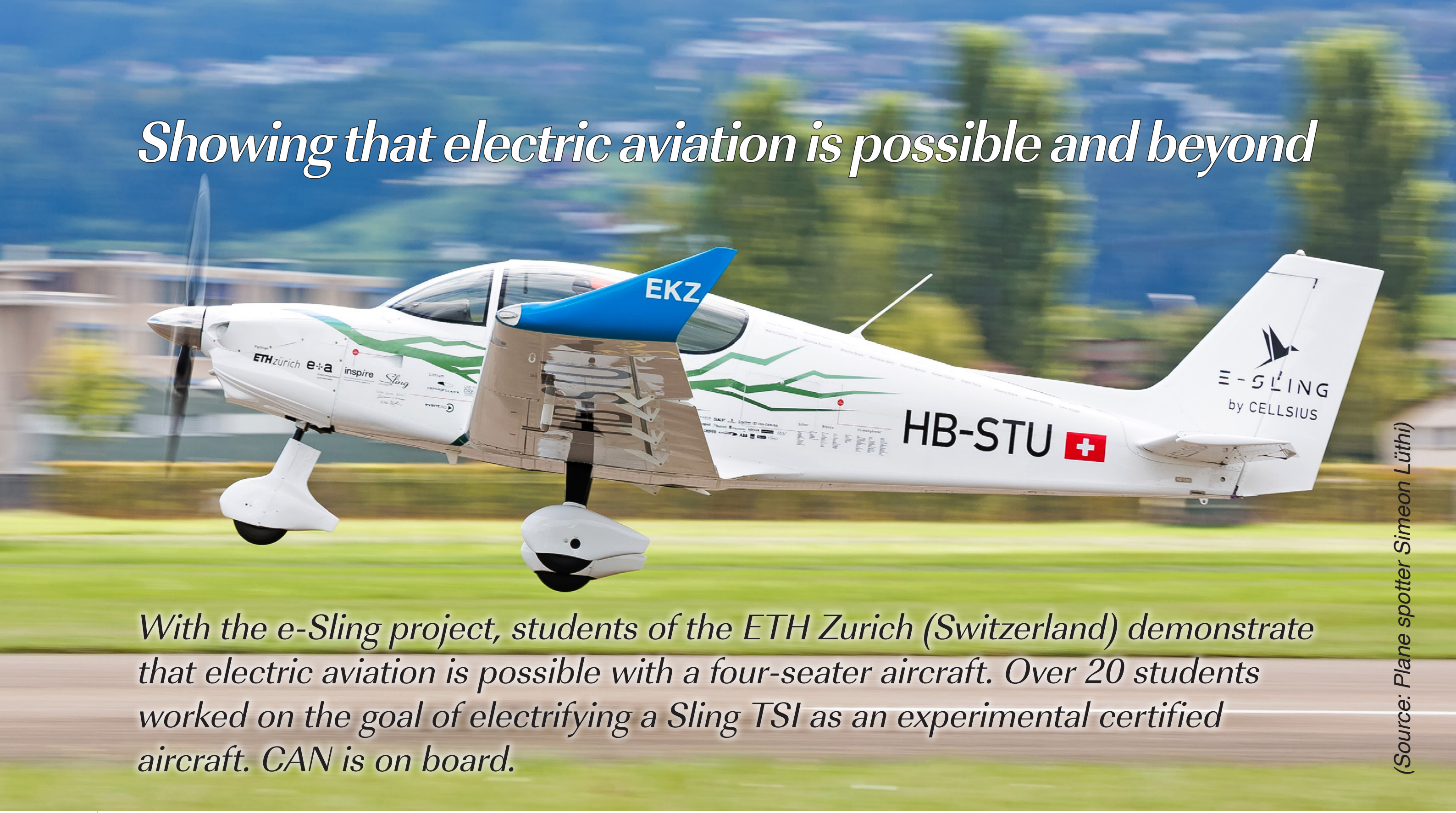
Showing that electric aviation is possible and beyond



(Source: Plane spotter Simeon Lüthi)

With the e-Sling project, students of the ETH Zurich (Switzerland) demonstrate that electric aviation is possible with a four-seater aircraft. Over 20 students worked on the goal of electrifying a Sling TSI as an experimental certified aircraft. CAN is on board.

The Sling TSI is a four-seater home-built aircraft from South Africa, which we have electrified in the last two years. Now we are doing 40h of test flights for the experimental certificate. And our new challenge for this year's students is to develop a fuel cell system for an aircraft to further improve the range and our field of research. The hydrogen drive train is planned to be built into a next aircraft, until then we have already started testing our system.

System architecture of the alpha project

The electric powertrain is entirely designed by us students. We developed the inverter with industry-leading silicon carbide power semiconductors, which powers the radial flux motor from our partner e+a Elektromaschinen und Antriebe. For our two battery packs we use over 2000 cylindrical battery cells with an integrated battery management system. The batteries are in the wings. Furthermore, we have a cooling system for the batteries and the motor, and of course a control system. Here is where CAN plays an important role in our system. All devices communicate with the CAN 11-bit identifier base frame format, without any higher-level protocols such as CANopen. CAN is used in order to ensure that the main devices have all the important information they need. And additionally, that we can use sensors which also communicate with CAN. We also do not need a separate communication protocol for our graphical interface, as the data is already on the network. This is used for our HMI (human-machine interface), for the pilot, and to send the data to a background server to further analyze the data.

We use one main CAN system with nodes for the inverter, ECU (electronic control unit - with a STM32H743ZI2 Nucleo, based on a Cortex-M7), BMS (battery management system) commander, current sensors in the batteries, voltage distribution box sensor, HMI controller, and the low-voltage inverter. Furthermore, we have a second CAN system just for the charging.

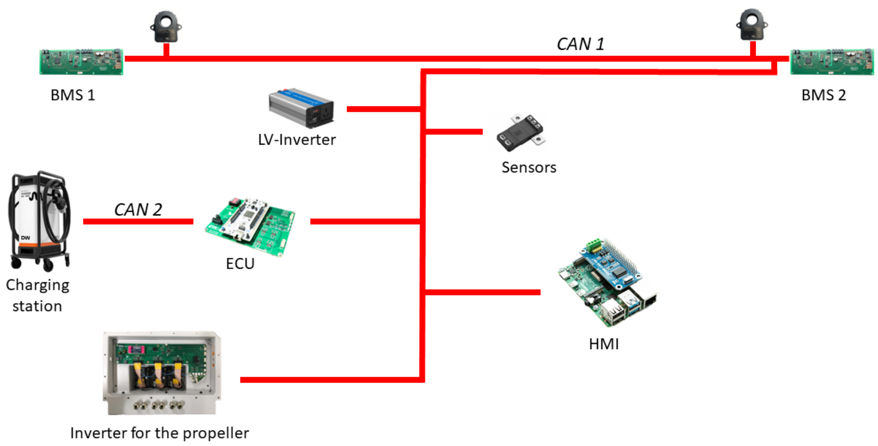


Figure 1: The CAN network in the e-Sling alpha project (Source: Cellsius)

Handling IDs and sending data

As mentioned above, we do not use a higher-level protocol. Therefore, we will explain how we handle the IDs for our nodes and how we manage to send the data. In the airplane we use the standard IDs, not the extended IDs, as we have no sensors which use the extended ID. For our data we have a large enough CAN-ID space. To know which device sends data frames, we have defined an ID space for every node. ▷

Figure 2: A range of companies and organizations supported the university to realize their project; CAN in Automation (CiA) helped to answer all CAN-related questions (Source: Cellsius)

Within the node we define which data is sent over which CAN-ID. If one measurement/data entity does not use the 8 byte of a single CAN data frame, which is mostly the case, we send several parameters either cyclic or event driven within the same ID. With this model we had the full control what we send with each frame. The downside is that it is not compatible with other systems, but as this does not matter for our purpose, we chose the path without a higher-level protocol such as CANopen.

Data recording and HMI

For the HMI in the cockpit, we use a Linux-based Raspberry Pi system to visually display all important information

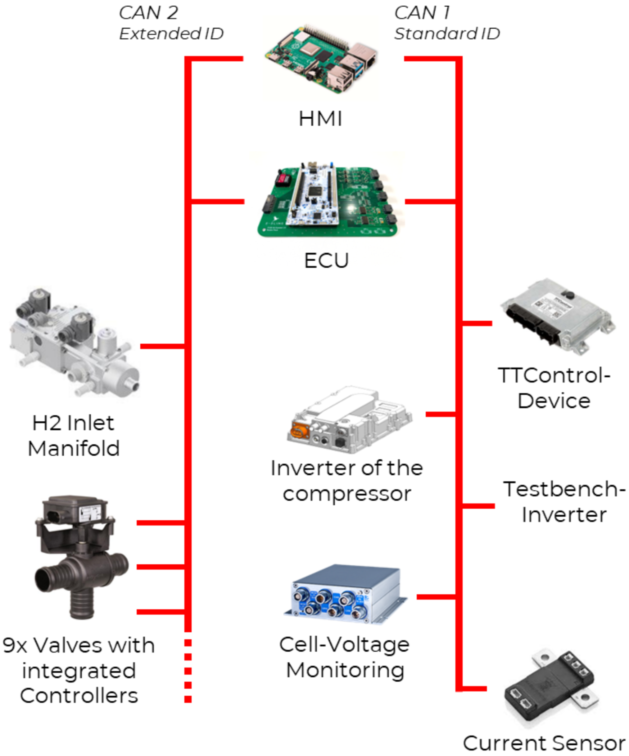


Figure 3: The CAN network in the latest project called H2 (Source: Cellsius)

to the pilot. We use the official CAN API (application programming interface) SocketCAN to read and send CAN data frames on a Linux-based system. With this approach we are very flexible to display additional data, as we can read all the data which is on the CAN network.

Furthermore, we use the Raspberry Pi to send all the data to our own server. On the server we built a surveillance tool for us developers. This graphical visualization of the data was extremely helpful for debugging purposes to support our fast development cycles. With the help of these Grafana plots we were able to detect faults early in our system, for example that one cell connection was bad. This also helped us to improve the stability of our system, especially with the electromagnetic coupling into the CAN network. It is also crucial to detect safety issues early while using the aircraft and to have an overview and feedback for the maintenance program.

CAN adjustments in the new e-Sling project H2

In our new hydrogen fuel cell project called "H2", we also use a CAN system as the heart of our system. Here we have divided the components into a network which uses the extended ID and one that uses the standard ID. For faster development we reused our ECU and a Raspberry Pi for the server interface from the e-Sling alpha project and the methodology how we define the CAN-ID spaces. In the hydrogen system we have a lot of controllers for which we send the steering data over the CAN interface. One controller is even a MIMO (multiple input multiple output) system which we have integrated into our ECU.

This autumn we successfully demonstrated that our fuel cell works on a test bench at the PSI (Paul Scherrer Institut). The new students are now improving this core technology that it fits into the airplane. Furthermore, they are developing the rest of the hydrogen system for an airplane such as the hydrogen tank and the electric system. ◀

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