Names
People

AEROWORKS: Summary for SBX's effort

Table 3.4a: Summary of staff effort.

ASL
now ETH-V4R (Margarita)
Skybotix

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total PMs
1. LTU	30	6	4	8	23	15	13	9	108
2. ETHZ	0	5	4	34	17	18	20	6	104
3. KTH	0	3	0	0	6	41	7	3	60
4. UT	0	3	27	13	13	7	4	2	69
5. UEDIN	0	4	0	64	0	6	4	2	80
6. UPAT	0	3	8	0	32	11	4	6	64
7. ASC	0	6	6	3	17	0	15	4	51
8. SBX	0	6	4	18	1	2	11	4	46
9. AIR	0	10	0	0	0	0	6	5	21
10. SKL	0	11	0	0	0	0	6	6	23
Total PMs	**30**	**57**	**53**	**140**	**109**	**100**	**90**	**47**	**626**

3 years

1 man month ≙ 7k CHF

note: ARW = Aerial Robotic Worker = UAV with sensing and manipulator onboard
The tasks most relevant to SBX are detailed below.

WP2: Applications, Requirements and Benchmarks

SBX: 6 PMs

Task 2.1 - Application scenarios (SKL, AIR, All partners involved)
Task 2.2 - Benchmark specifications and related performance measures (AIR,SKL, All partners)
Task 2.3 - Platform and overall system requirements (ASC, SBX, All partners involved)
The detailed specifications for the aerial robots, their sensory systems, their autonomous perception, mapping & navigation capabilities, their flying qualities, the manipulator workspace and maximum applicable forces, as well as specifications regarding the communication capabilities and the collaboration autonomy of the team of the aerial robotic workers will be the outcome of this task. Additional concern will be dedicated to the incorporation of requirements identified within Task 2.1, for intuitive ground-station interfaces available to technical experts, which will enable the human operator-guided semi-autonomous operation. All partners will be strongly involved with the definitions of their concern.
Task 2.4- Final validation scenario definition (SKL, All partners involved)

WP3: Dexterous Aerial Manupulator

SBX: 4 PMs

"SBX will assist in the control design and physical interaction operations of the manipulator"
Task 3.1: Dexterous manipulation system design (UT,LTU,ETHZ,UPAT,SBX,ASC)
Task 3.2: Interaction control of the single aerial robotic worker (UT,LTU,ETHZ,UPAT,ASC,SBX)

WP4: Collaborative Perception, Mapping and Vision for Manipulation

SBX: 18 PMs

Task 4.1 - Real-Time vision-based SLAM for each ARW (ETHZ, UEDIN, SBX, LTU, KTH, UT)
Task 4.2 – From vision-based SLAM to dense reconstruction (UEDIN, SBX, LTU, ETHZ, UT)
With SLAM comprising the first step towards the spatial awareness of a robot, it is well understood that for a robot to interact with its environment, the traditionally sparse feature-based SLAM methods are not sufficient. In the AEROWORKS paradigm, there is an increased level of 'scene understanding' necessary to permit interaction of the manipulator carried on an ARW with the environment. To this end, we aim to study powerful dense reconstruction methods [34] from the Computer Vision literature, with the aim of realising them within the context of the time-critical and computation- and power-limited robotic setup in this project. Driven by the need for CPU implementations especially within Robotics, relevant works have been emerging, albeit their operation in real-time is still a challenge and a hot research topic.
Following the development of real-time vision-based SLAM for each ARW in T4.1, this task will

address dense scene reconstruction, using the feature-based SLAM map as a basis. Unlike high-performing dense mapping alternatives, here the focus is on techniques that can realistically be applied on the envisioned scenario of a power- and computation-independent ARW. As a result, our study into denser mapping strategies will avoid power-hungry GPUs and rather aim for a methodology employable on CPUs. While the use of a more powerful ground station for post-processing of information will not be excluded, the aim here is to enable the acquisition of at least a first 'draft' of a dense map in real-time by each ARW.

Task 4.3 - Collaborative ARW Sensing and Mapping (**UEDIN,** ETHZ, LTU, KTH, UT, SBX)

Task 4.4 - Vision for Aerial Manipulation (**UT**, SBX, LTU, ETHZ, UEDIN)

This task aims at utilizing the improved perception capabilities of the collaborative team of ARWs to influence and improve the manipulation and physical interaction capabilities of the aerial robotic workers, both as single and as cooperative robots manipulating objects. To achieve this task, the approach of *collaborative visual stereo rig* will be extended to improve the manipulation capabilities of the team of collaborative ARWs. Multiple ARWs can simultaneously detect a target and share their relative information in order to improve the estimate of the position and orientation of a target object in the environment. The visual information of multiple ARWs will therefore be fused to obtain common absolute information of the position of the target objects that are necessary requirements for the planning of the trajectories and the capability of the ARWs to manipulate an object. Moreover, the reduced uncertainties in the estimation of the object pose in the shared environment influences the control of the interaction of the single ARWs and increase the performances of the group of ARWs performing manipulation tasks. As proposed in Task 3.1, the manipulators will be constructed in a way that variable compliance will be implemented to perform safe interaction, by minimizing the effect of impacts with the end effectors. The way the equivalent end-effector stiffness is set depends on the uncertainties of the estimate of the object to interact with. The information about the uncertainty is dependent on the amount of ARWs collaborating in this estimate and will therefore influence the stiffness profile and the interaction performances of the single ARW operating in the environment. As a result, the use of collaborative object pose estimation will allow better control of the compliant behaviour of the single ARW, leading to improved interaction and manipulation skills.

Task 4.5 – Fail-safe Robust Estimation (**SBX**, UEDIN, ETHZ, LTU, ASC)

This task serves for purposes of robustification and robustness against estimation/sensor faults and failures. The framework will be extended to incorporate up to four monocular cameras, state estimation quality will be automatically assessed and failures will be detected and compensated. GPS carrier-phase measurements will also be integrated in the visual-inertial state estimation framework.

WP5: Aerial Robotic Workers Development and Control

SBX: 1PM

WP6: Collaborative Planning and Control for Inspection and Aerial Manipulation

SBX: 2PM

"SBX is especially involved in the Task 6.2 research aspects"

Task 6.2 Collaborative Path-Planning and Coverage Control for Inspection (**KTH**, LTU, ETHZ, UEDIN, UPAT, SBX)

This task relates with the development of distributed collaborative path-planning algorithms for inspection operations. The path planner for each robot should be collaborative in the sense that it has to guarantee collision avoidance with other members of the team as well as stabilization to the desired configuration points in 3D. These have to be decided by an online 3D coverage algorithm that should take into account the inspection mission as well as the dynamics of the UAVs. As AEROWORKS aims to achieve increased autonomy as well as mission completeness, the proposed algorithms will go beyond fully decoupled task-assignments solely based on individual specification but will also incorporate environment and perception uncertainties as well as heterogeneity of the robotic systems into the optimization process, whose cost function will aim at maximizing the coverage of the inspected area in a collaborative manner. This task expands upon the path-planning algorithms to be developed within Task 6.1 and aims at enabling key system abilities such as robot-to-robot interaction and configurability.

WP7: System Integration and Evaluation

SBX: WP lead, 11 PMs

Task 7.1 - Integration (SBX, ETHZ, ASC, AIR, LTU, UT, UEDIN, KTH, UPAT**)**

AEROWORKS aims at deploying autonomous aerial robotic infrastructure inspection and maintenance solutions characterized by advanced system abilities and increased technology readiness level. Consequently, subsequent integration cycles will take place, including efforts related with:

- Integration of the aerial manipulator hardware and device interface towards developing each single aerial robotic worker and deploying it with a modular control interface.
- Integration of the perception and advanced state estimation modules and algorithms to the aerial robotic workers. As all advanced estimation and perception algorithms take place in the AEROWORKS Sensing and Processing Unit, convenient and safe integration is envisaged.
- Integration and test-cases based evaluation of the autopilot functionalities that enable the active aerial dexterous (co-)manipulation by the ARWs team.
- Integration of the baseline teleoperated inspection and aerial manipulation control algorithms that enable the execution of infrastructure maintenance operations with a non-specifically trained human-in-the loop.
- Integration of the collaborative planning and control for structural inspection and maintenance operations. This integration task will also be followed by extensive evaluation in order to ensure that all the desired functionalities are successfully achieved and all hardware/software components are aligned.
- Development of the ***AEROWORKS intuitive-to-use Ground Control Center***

The AEROWORKS successful integration plan relies on the selection of unified hardware and software as well as the fact that it builds upon all the recent and most successful developments of the partners. Through proper task assignment, partner complementarities and well-scheduled integration weeks, the project will reach the level of mature and well-integrated technological solutions, systems and prototypes.

Task 7.2 - Demonstration (ETHZ, AIR, SKL, SBX, LTU,UT, UEDIN, KTH, UPAT**)**

Task 7.3 - Performance Assessment (ETHZ, AIR, SBX, LTU, UT, UEDIN, KTH, UPAT, AIR, SKL**)**

WP8: Dissemination, Promotion and Exploitation

SBX: 4 PMs

Task 8.3 – Strategic Market-based Dissemination (AIR, LTU, ETHZ, UPAT, ASC, SBX, SKL)

"...SBX will aid in order to increase the visibility of the project results in the industrial/commercial robotics sector. "