EXOTRAINER

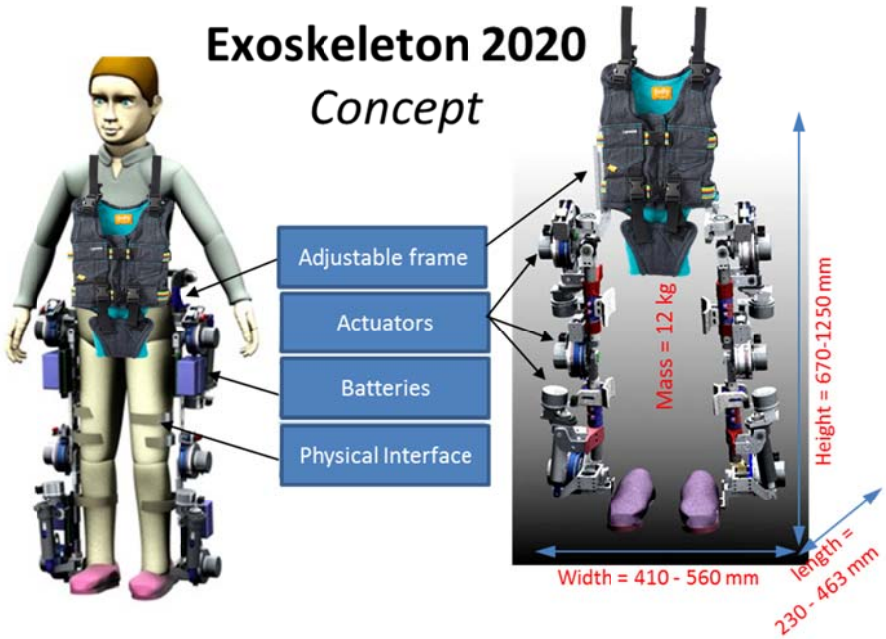
Period 01.09.2015-30.10.2015

During the period Sept-Oct 2015 EXOTrainer RTD activity progressed in line with the initial workplan. Progress was made to the following tasks:

- EXOTrainer.2.2: Detail design of components: CAD mechanical design.

  The resulting CAD model is shown in Demo no. 2: Graphical video showing the final exoskeleton concept matching requirements and specifications set in Task 1.

  https://youtu.be/U3nl7Ao5b8U



- EXOTrainer.2.3: Selection of commercially available orthotics components and design of custom elements and adjustments.

Orthotics components selected for SMA children:

1. Body arnes: Required to safely maintaing trunk upright and to attach to the exoskeleton structure.

2. Shoes: Therapy shoes are made on extra depth lasts. They provide extra support through medical and lateral extended heel stiffeners and a removable, anatomically shaped full length footbed. Specifically designed for Children who need
    - shoes with extra support;
    - Neuro-physical problems;
    - Varus or valgus instability;
    - Painful or pressure sensitive feet.

3. Design of custom adjusments

Custom adjustments to the leg segments manufactured in comformable thermoplastic material for each of the voluntary patients.

Dissemination activities during this period:

Number	Name	Tasks no.	Due	Status	Comments, especially references, links, … Please send images, videos, press material, etc. in the mail or give a download link
8	First Meeting on Technological Innovation and low cost for Rare Diseases and Disabilities. Exoesqueletos de marcha: un horizonte en la terapia de las enfermedades neuromusculares en la infancia. Dra Elena García. CSIC	*1*	7/10/2015		**State Reference Center of Care for People with Rare Diseases and Their Families (CREER) http://www.creenfermedadesraras.es/InterPresent2/groups/imserso/documents/binario/programaencuentroinnovacion.pdf**

Period 01.11.2015-31.12.2015

During the period Nov-Dec 2015 EXOTrainer RTD activity progressed in line with the initial workplan. Progress was made to the following tasks related to hardware integration and preliminary testing:

EXOTrainer.3.1: Dimensioning and selection of actuators and electronics: Based on the CGA models (Clinical Gait Analysis) by Professor Kirtley. This model is initially particularized for

a child of 30kg and will add a weight of 10kg exoskeleton. Selected walking speed is 0.6m / s. The analysis is shown in the following table:

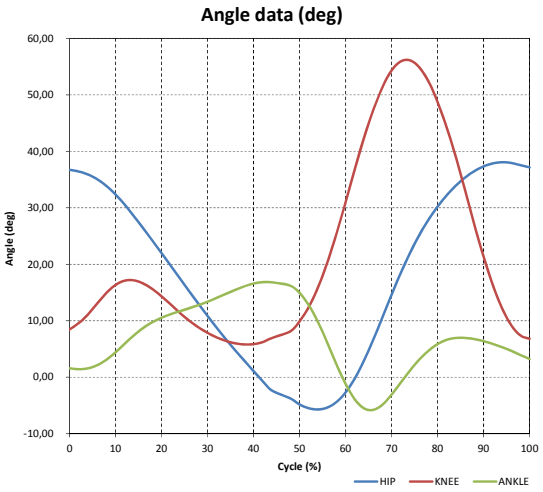
Gait Parameters

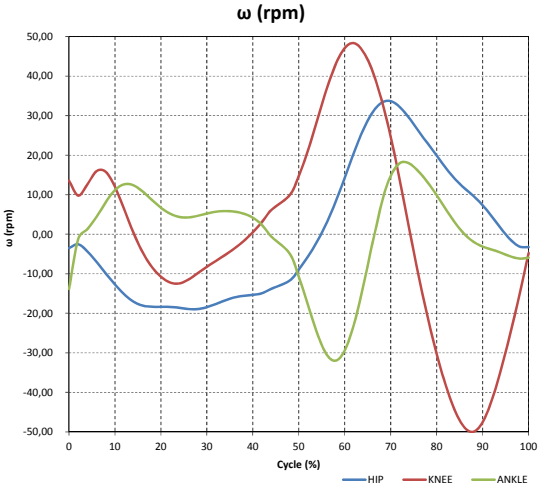
Mass	**40**
Leg Length	**0,50**
Speed (m/s)	**0,60**

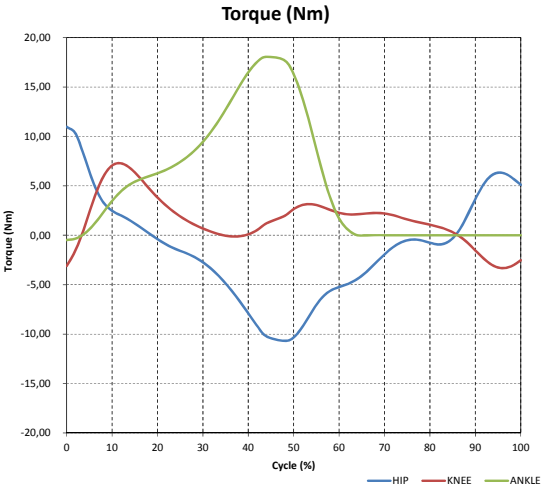
Normalized Speed (dimensionless)
0,27

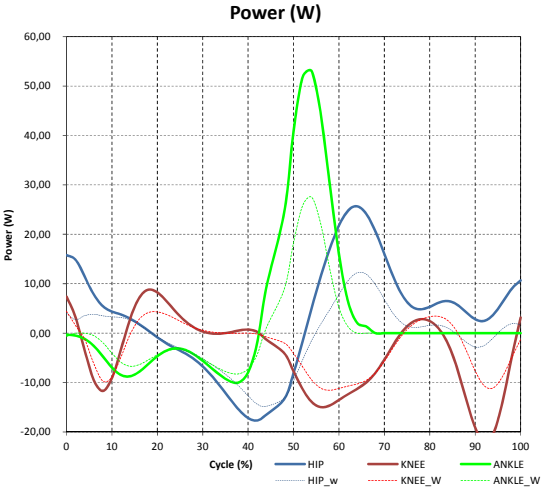
Cycle lenght (m)	**0,598**
Cycle Time (s)	**0,997**

With this we can represent the parameters of the three joint angles, the torque needed and mechanical power at each joint.

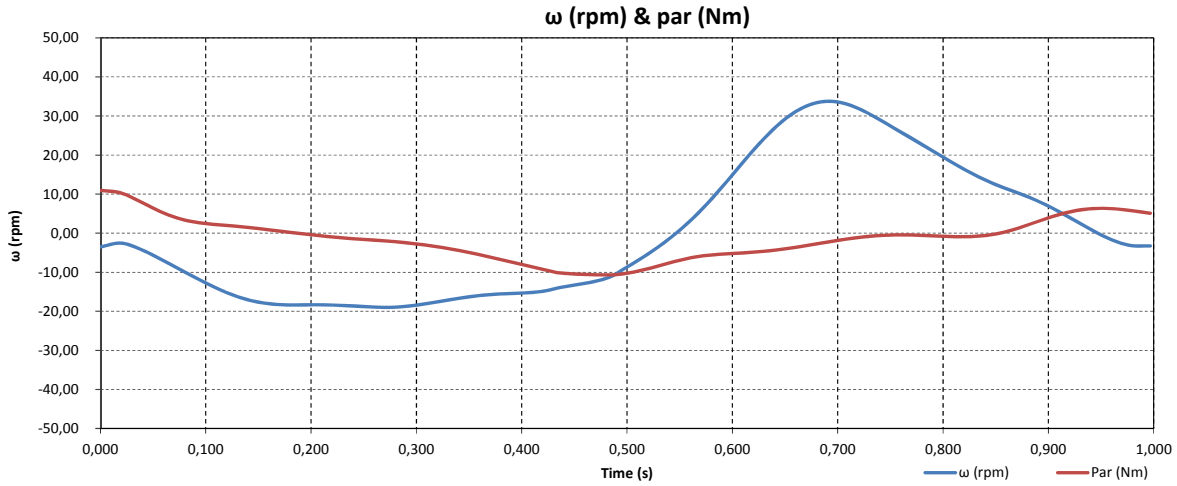






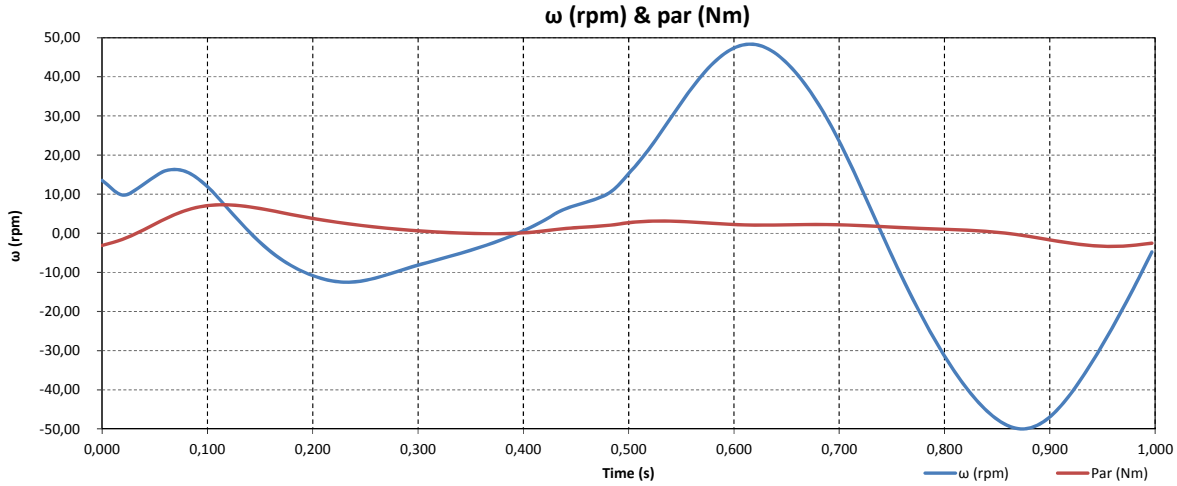


Hip Power dimensioning:



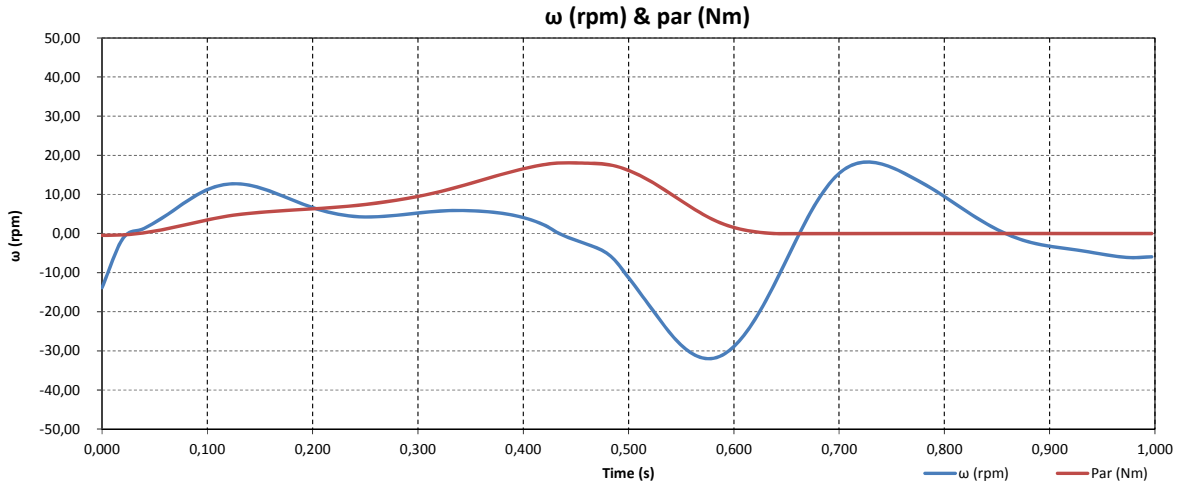
T avg =	5,00 Nm	**T max =**	**10,00 Nm**
N avg =	15,94 rpm	**N max =**	**35,00 rpm**

Knee Power dimensioning:



T avg =	4,59 Nm	**T max =**	**10,00 Nm**
N avg =	21,70 rpm	**N max =**	**50,00 rpm**

Ankle Power dimensioning:



T avg =	8,12 Nm	**T max =**	**20,00 Nm**
N avg =	12,48 rpm	**N max =**	**35,00 rpm**

Battery Power requirement:

	Mechanical output			**DC/DC motor OUT**		
	Hip	**Knee**	**Ankle**	**Hip**	**Knee**	**Ankle**
Pm avg (W)	8,35	10,43	10,61	13,91	17,38	17,68
T avg (Nm)	5,00	4,59	8,12	0,052	0,048	0,085
ω avg (rpm)	15,94	21,70	12,48	2550	3473	1996
T max (Nm)	10	10	20	0,104	0,104	**0,208**
ω max (rpm)	35	50	35	**5600**	**8000**	**5600**

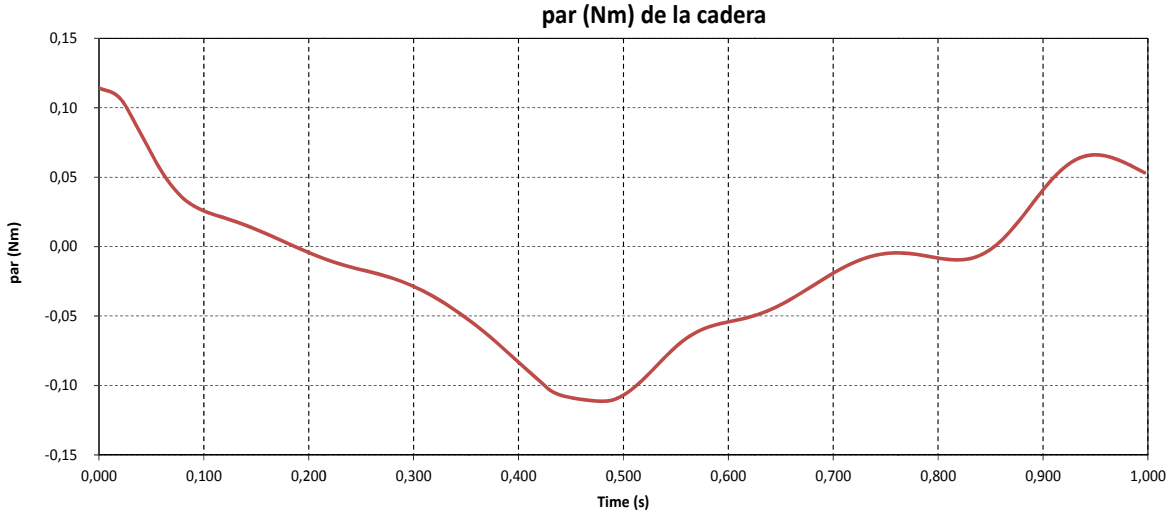
- EXOTrainer.3.1: Optimization of sensorial system acquiring the user state, the robot state and user-robot interaction. Pressure sensors, force/torque sensors, angle and velocity sensors, acceleration sensors (inertial measurement units) were integrated.

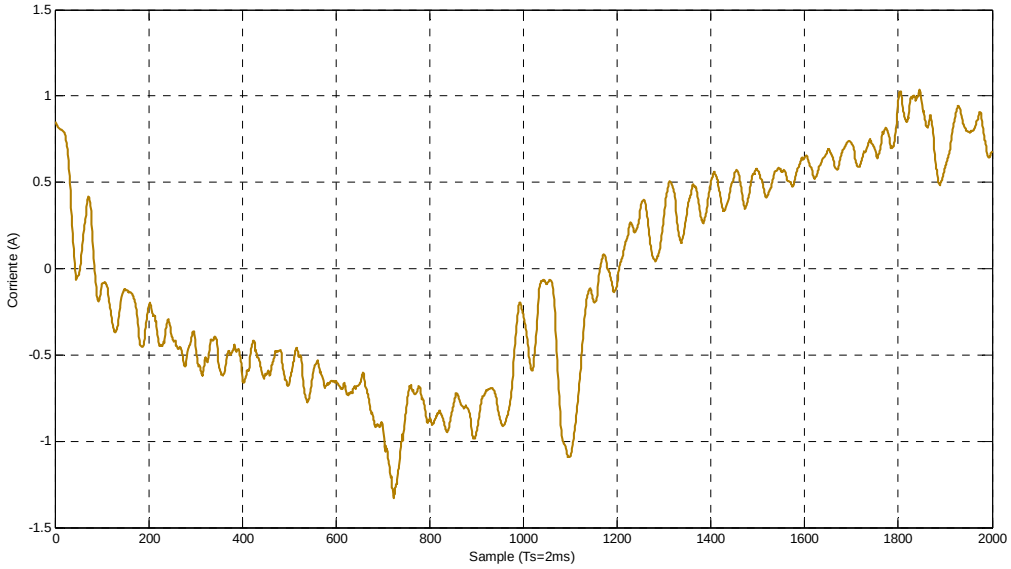
Control	
Master Controller (off-the shelf)	• HW: National Instruments (MyRIO). • SW: LabView platform
Slave controllers (ad-hoc)	• Motor drives: Maxxon ESCON 50/5 (TBD) • Microcontroller: ATMEL (TBD)
Sensing	
Motor position & speed	• Hall effect + optical encoder MILE
Joint position	• Absolute magnetic sensor AS5045
Orthotic foot	• 8 x Sparkfun Force Sensitive Resistor 0.5'' ∅ sensing area
Inertial unit (TBC)	• SparkFun IMU Fusion Board ADXL345 & IMU 3000
Communications	
Battery	• SIMBUS (TBC): Monitoring SoC
Master & Slave Controllers	• SSI

- EXOTrainer.3.2: Integration into the exoskeleton and partial tests. An example of integration tests at the hip joint:

In the new exoskeleton with 10 joints , first preintegration tests have been conducted controlling leg joints. At this state anly position control is executed at the motors and have not yet implemented the force control.

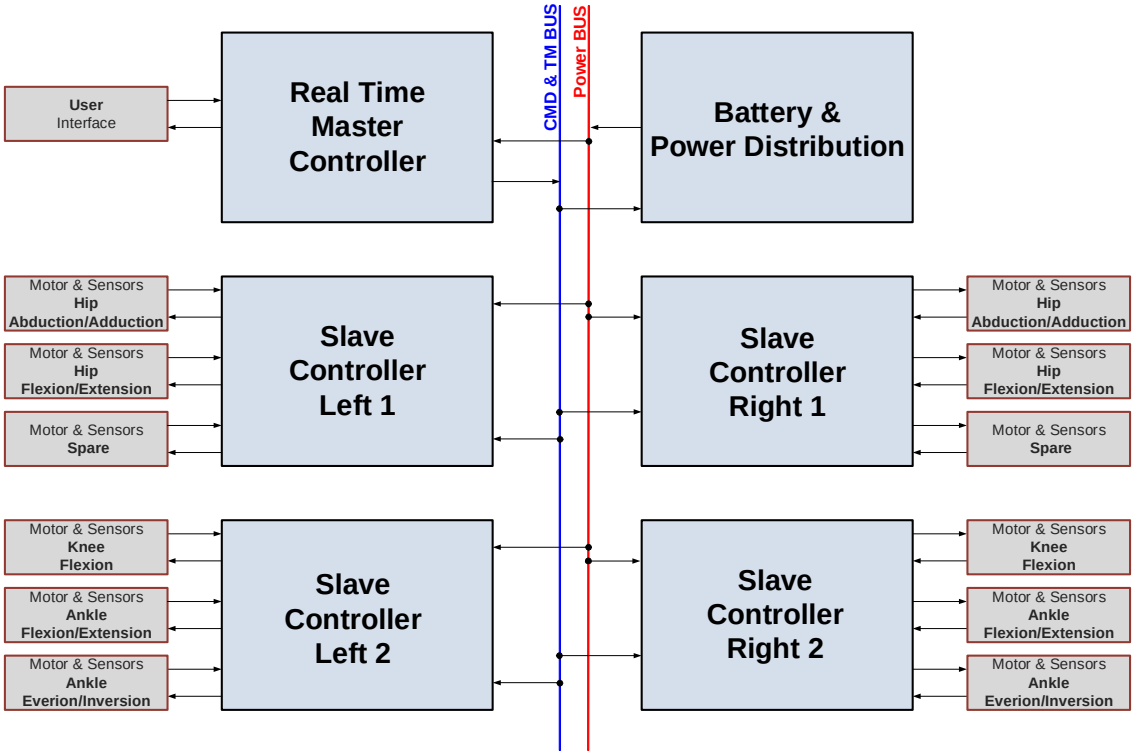
At this preliminary stage the tests allow us to determine the quality of the estimate of the requirements made in the previous section. The envelope of the current observed in Figure is similar to that estimated, but there are some fluctuations due to incorrect adjustment of the gains of the drivers.





Comparison of the estimated torque at the hip compared to current measurement provided by the ESCON.

- EXOTrainer.4.1: Joint-space controller and integration. The joint-space controller is implemented as an impedance controller, making use of the adjustable-stiffness actuators (ARES) currently installed in the exoskeleton's joints. Position and speed references coming from the Task-space controller will be compliantly followed by the actuators, respecting a parallel requirement of articular force.



The following video shows the behaviour of the joint when a zero-force control scheem is programmed: https://youtu.be/FAqlX-9Fn8Q

By the end of this reporting period the EXOtrainer exoskeleton has been fully assembled and tested in operation. A video showing exoskeleton in motion is shown in https://www.youtube.com/watch?v=W8aFiGn6V80

Dissemination activities during this period

Number	Name	Tasks no.	Due	Status	Comments, especially references, links, … Please send images, videos, press material, etc. in the mail or give a download link
9	**EXOTrainer Demonstration**	*1-3*	3/12/201		Presenting EXOTrainer Exoeskeleton for Spinal Muscular Atrophy during the *International Day* of People with *Disability,* Museo de las Ciencias Príncipe Felipe, Ciudad de las Artes y las Ciencias, Valencia, Spain https://youtu.be/ItDcoLBmUiw

Deliverables & Milestones:

Elena: Please indicate below the milestones and deliverables were the due dates / deadlines need to be updated on the monitoring platform. I know that we discussed this and I think we updated everything, but please indicate if there is still anything which is not okay.

The next milestone and deliverable are due then end of this month (31.01.2016). Can you briefly update us on the status – about three weeks before due date?

Milestone 1 and 2 due dates and tasks involved have not been corrected yet, and Milestone 6 is missing:

MS number	Milestone name	Task(s)	Due date	Means of verification
M1	Agreement on Requirements and specifications for EXOTrainer	1	31/07/2015	Agreement among clinical, technical partners and patients
M2	EXOTrainer concept approved	1-3	31/10/2015	Assessment by clinical partner
M6	Clinical proof of concept	5	31/10/2016	Clinical assessment with external evaluation

Dissemination activities:

Please check the due dates of the dissemination activities. Again, I know that we have discussed this during the last monitoring session and I apologize for not keeping track of things properly. So, please be so kind and communicate to me in this document all the due dates which are wrong. And please complete the table for me for those of the KPIs which you have already reached. Thank you.

1	**CAPFEST 2015** Festival of Capabilities, Arona, Tenerife, Spain	*1-3*	4/12/2015		Invited Speaker at International Conference for the Disabilities CAPFEST 2015.

	"Gait exoskeletons for the therapy of Spinal Muscular Atrophy". Dra Elena García. CSIC				

Technical KPIs Milestones:

The same as with the dissemination milestones. The due dates of some had to be corrected and you have (if I remember correctly) advanced at least one of them. Please send me the correct table below so that I can make sure that due dates are updated properly.

Please report on all KPIs also in the respective monitoring blogs and also upload relevant material there. Thank you.

TECHNICAL KPIs				
No.	**Indicator**	**Task**	**Exp. Date**	**Verification**
1	DOF identification	1	**31/10/2015**	**videos/images showing how the DOFs match with requirements stated in Milestone 1**
2	Improved Kinematics for children: size, weight, self-balance, no thoracic control needed.	1,2,3	**31/10/2015**	**Drawings and pictures of kinematics and orthotic complements. Include a reference in the KPI coment.**
4	Adjustable to size of patients between 4 – 8 years children	1,2,3	**Partial tests: 31/12/2015. Final verification: end of clinical trial, 31/10/2016**	**Pictures showing size adjustment**
5	Sensor Integration	2,3	**Partial tests: 31/12/2015. Final verification: end of clinical trial, 31/10/2016**	**Pictures, Video**
6	Gait control (Generation of foot and joint trajectories)	4	**Partial tests 28 Feb 2015. Final verification: end of clinical trial, 31/10/2016**	**Video**
3	3D mobility	1,2,3	**Partial tests: 31/12/2015. Final verification: end of clinical trial, 31/10/2016**	**Graphical simulation showing 3D mobility**