Per sostenere l'esame di Sistemi e Sensori Radio (6 CFU) – non più erogato-, avendo seguito il corso di Satellite Payloads (9 CFU):

a) **Seguendo il programma dettagliato delle lezioni che segue, si possono omettere le parti in rosso**
b) **Chi ha sostenuto positivamente le prove in itinere, può prenotarsi per la prova orale di satellite Payload, scrivendo nelle note "SSR" seguito dal numero di prenotazione INFOSTUD all'esame di sistemi e Sensori Radio**

Payloads 2022-2023 - Lesson's log

#	date	time	Topic	Teaching material
	27/09/2022 Room 12	13:00-15:00	- lecture postponed	
	28/09/2022 Room 9	12:00-14:00	- lecture postponed	
	29/09/2022 Aula 32	10:00-12:00	- lecture postponed	
	30/09/2022 Room 8	12:00-14:00	- lecture postponed	
1-2	04/10/2022 Room 12	13:00-15:00	- Introduction to the course, web page, teaching material, "in itinere" tests and final exam structure - The three main payload categories: TLC, Satellite Navigation, and Earth Observation. - Common characteristics, specific orbital requirements, and peculiarities.	Slides: 01_Payload_intro https://youtu.be/MrBYYm8mPTk
3-4 GNSS #01	05/10/2022 Room 9	12:00-14:00	- Principles of operation of the global navigation satellite systems - Positioning in 1D, 2D, 3D and the required hypotheses - Pseudorange measurements, clock errors and synchronization problems. 4D solution and PVT estimation	Slides: 31_GNSS_principles_v2_part1 https://youtu.be/H6PdJkd9zLM
5-6	06/10/2022 Room 32	10:00-12:00	- Link budget basics - Free-space wave propagation rules: attenuation and phase rotation - Received Power at range R with isotropic TX antenna - Directional antenna: Directivity and Gain - Received power with directional antenna, Antenna Gain vs Aperture: received power formulation; - EIRP & G/T merit figures; - Directional antennas: beam steering/attitude control requirements - Thermal noise power and SNR definition	Slides: 02_Payload_linkbudget https://youtu.be/3h8eNbG-HBM
7-8	07/10/2022 Room 8	12:00-14:00	- Free-Space Loss (received Power with FSL) - Definition and use of decibels - Numerical examples - Numerical evaluation of Free space Loss - Received power & SNR (linear and dB)	Slides: 02_Payload_linkbudget_part2 https://youtu.be/RPSSSVs6qEo

			- Typical case studies and numerical examples	
9-10	11/10/2022 Room 12	13:00-15:00	- Introduction to space-based radar systems	slides: 21_Radar_fundamentals_part1 https://youtu.be/dc1eSDFFASo
11-12 GNSS #02	12/10/2022 Room 9	12:00-14:00	- Estimation of satellite positions and clock errors from the Earth: Reference/Monitor stations, Master Control Station and the inverse GNSS equations. - Transferring the required data to the user receivers: predictions, fitting to parametric functions, upload and update every 2 hours. Global structure of the Ground Segment. - Modified Keplerian orbital functions as parametric model for satellite positions: the 16 numbers of the GNSS ephemeris - The 3 GPS segments: Space, Ground, User	Slides: 31_GNSS_principles_v4_part2 https://youtu.be/MQMTO7iwW7Q
13-14	13/10/2022 Room 32	10:00-12:00	- Power issue from the case studies - Earth surface Coverage vs satellite height - Coverage from geostationary orbit, Clark, example with Inmarsat Constellation - Coverage with assigned minimum elevation angle: consequent increase in minimum satellite number for global coverage, antenna beam apertures and maximum signal delay – antenna gain as a function of the height - The example of the Starlink constellation with its 3 shells. - Using spot beam from GEO for higher antenna gain is desired areas, also shaped – example of TV broadcast	Slides: 02_Payload_linkbudget_part3 https://youtu.be/v5DycWuCrg0
15-16	14/10/2022 Room 40	12:00-14:00	- Rules of thumb for antenna Gain from beamwidths - Maximum power transfer condition - definition and average power of Thermal noise, - Temporal and spectral characteristics of thermal noise - Thermal noise through filters and receiver Noise Bandwidth - Equivalent thermal noise level at the receiver input	Slides: 02_Payload_linkbudget_part3 https://youtu.be/rcf8SDQEQHI
17-18	18/10/2022 Room 12	13:00-15:00	- Radar equation, dynamic range; pulsed vs. CW radar. - The radar detection, Threshold, detection performance; Pfa & Pd; Required SNR - The power problem for the detection in the far-range and the need to increase SNR / received echo energy - The use of long radar pulse: PRO's and CON's; rectangular vs phase modulated waveforms.	slides: 21_Radar_fundamentals_part2 https://youtu.be/4gbuJ7u3Z2I
19-20 GNSS #03	19/10/2022 Room 9	12:00-14:00	- A model for clock error and the parametric function for the satellite clock correction - The Navigation message and its timing	Slides: 31_GNSS_principles_v4_part2 https://youtu.be/XzXa6rl2lak
21-22	20/10/2022 Room 32	10:00-12:00	- Real vs. ideal noiseless receiver; noise contribution from the receiver - Equivalent noise at the receiver input; Noise Figure and SNR degradation	Slides: 02_Payload_linkbudget_part3 https://youtu.be/FgEuf3iPcJA

			- Equivalent noise temperature and relation to noise figure. - Noise temperature and noise figure for cascaded devices - Example of evaluation	
23-24	21/10/2022 Room 40	12:00-14:00	- Antenna Noise temperature as combination of cosmic background, atmosphere, antenna and waveguide - Level of the contributions to the antenna noise from ITU 372 - System noise at different ports of the receiver - Example of System temperature evaluation and improvement with cryogenic receivers	Slides: 02_Payload_linkbudget_part4 https://youtu.be/PkN-ydmS5-o
25-26	25/10/2022 Room 12	13:00-15:00	- Radar measurement accuracy: range, and Doppler - Relationship between accuracy, resolution and SNR - Monopulse antenna and monopulse radar measurements - Radar measurement accuracy: azimuth, elevation	slides: 21_Radar_fundamentals_part2 https://youtu.be/h5xBiNTdlZw
27-28 GNSS #04	26/10/2022 Room 9	12:00-14:00	- The GNSS navigation solution and its implementation - Propagation delay and its relationship with the index of refraction	Slides: 32_GNSS_solution https://youtu.be/mfQ0tUGAqPo
29-30	27/10/2022 Room 32	10:00-12:00	- The Binary symmetric channel - Error detection and ARQ approaches - Modulo-2 operations and single-parity-check code - Channel coding and error correction, Repetition code	Slides: 03_Payload_Discrete_Probability_and_Coding_v2_part1 https://youtu.be/QIECI7LGZDo
31-32	28/10/2022 Room 40	12:00-14:00	- Hamming Codes - Implementation and operation of the (7,4) Hamming code; Systematic version of the code. - Generic Block codes. Generation and Parity Check Matrix. Syndrome for error detection and correction	Slides: 03_Payload_Discrete_Probability_and_Coding_v2_part1 https://youtu.be/SLTUB9q6ASs
			- November 1st – All Saints	
33-34 GNSS #05	02/11/2022 Room 9	12:00-14:00	- Tropospheric error and mask angle - Ionospheric error and its correction - Range and phase measurement - Dual frequency correction techniques	Slides: 32_GNSS_solution https://youtu.be/ithczhLAa_Y
35-36	03/11/2022 Room 32	10:00-12:00	- Hamming Distance between binary sequences - Error detection and correction capability of a block code as a function of its Hamming distance - Cyclic codes and polynomial implementation of coding, decoding and syndrome evaluation. CRC codes. - The characteristics of the BCH and Reed-Solomon codes families for multiple errors correction.	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part2 https://youtu.be/vzD4I7zWi80
37-38	04/11/2022 Room 40	12:00-14:00	- Definition of probability: classical, frequentist, and subjective approach. - Basic probability; probability of union and intersection and examples related to binary sequences and errors in binary transmissions - Probability function - Distribution function	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part2 https://youtu.be/3bksw08vutk

			- Bernoulli random variable and error probability	
39-40	08/11/2022 Room 12	13:00- 15:00	- Closed loop estimation and tracking radar - Usage of scanning radar, conical scan and Monopulse for closed loop tracking - Thermal noise and angular accuracy	slides: 21_Radar_fundamentals_part2 https://youtu.be/2W8Au8_UeVA
41-42 GNSS #06	09/11/2022 Aula 9 PL	12:00- 14:00	- Usage of GNSS waveforms for ranging - Requirements for GNSS waveforms - LMS and their generation with shift registers - Properties of LMS and their cyclic autocorrelation - Generation of the C/A codes and their properties	Slides: 33_GNSS_signal https://youtu.be/qBpGrgnHkMU
43-44	10/11/2022 Room 32	10:00- 12:00	- Binomial distribution - Use of the Binomial distribution to evaluate error probability - Error detection probability evaluation using single parity bit code - Symbol and Bit Error probability using error correction codes - Examples and exercises	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part3 https://youtu.be/fdl6oGhvun8
45-46	11/11/2022 Room 40	12:00- 14:00	- Averages and Expected Values of function of random variables - examples - Noncentral and central moments - Mean and variance - Mean and variance of Binomial distribution	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part3 https://youtu.be/2YacBU6kzZI
47-48	15/11/2022 Room 12	13:00- 15:00	- Matched Filter (MF) derivation - MF interpretation and comparison to the inverse filter - MF output and signal autocorrelation - RECT signal MF - Waveforms with compression ratio >1 - The Chirp signal	slides: 22_Radar_pulse_compression https://youtu.be/1fWgyhYeGjs
49-50 GNSS #07	16/11/2022 Aula 9 PL	12:00- 14:00	- C/A and P-code - GPS carrier generation and frequency allocation - GNSS receiver scheme	Slides: 33_GNSS_signal 34_GNSS_receiver https://youtu.be/soCW3NtXMQ8
51-52	17/11/2022 Room 32	10:00- 12:00	- Conditional probabilities - Total probability Theorem - Bayes Theorem - Amount of Information - Entropy	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part3 https://youtu.be/9DoRowYIMuQ
53-54	18/11/2022 Room 40	12:00- 14:00	- Entropy of a binary source - Shannon 1st theorem (source coding) - Conditional Entropy of discrete memoryless channel - Channel Mutual Information - Channel Capacity - Mutual Information and Capacity of Binary Symmetric Channel	Sides: 03_Payload_Discrete_Probability_and_Coding_v5_part3 https://youtu.be/wcVQhBQrpjg
55-56	22/11/2022 Room 12	13:00- 15:00	- Characteristics of the chirp signal - Spectrum of the chirp and approximation for high compression ratio - Output of the matched filter for chirp signal - Sidelobe and sidelobe control filters	slides: 22_Radar_pulse_compression https://youtu.be/BefKIQiy12Q

57-58 GNSS #08	23/11/2022 Aula 9 PL	12:00-14:00	- Block diagram of the GPS receiver - Satellite signal search procedure in delay and Doppler frequency - Time To First Fix and number of receiving channels - Closed loop operation for the accurate estimation of the pseudoranges (discriminator, waveform generator with NCO and loop filter)	Slides: 34_GNSS_receiver https://youtu.be/QygkaM_HehY
59-60	24/11/2022 Room 32	10:00-12:00	- Shannon 2nd Theorem (Channel Coding) - Specific application to the BSC - Convolutional codes - Concatenated codes as a way to get close to channel capacity with low complexity - Elements for Turbo codes and LDPC codes	Slides: 03_Payload_Discrete_Probability_and_Coding_v7_part4 https://youtu.be/VLdB5RoFuAw
61-62	25/11/2022 Room 40	12:00-14:00	- Continuous random variable - Distribution Function, Probability Density Function - Example with uniform PDF - Expected values and moments for continuous r.v.s - The Gaussian PDF and Gauss error theory - Mean and variance of the Gaussian PDF - the Central Limit Theorem	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part1 https://youtu.be/TLOGa5C79FY
63-64	29/11/2022 Room 12	13:00-15:00	- Radar Imaging payload: radar antenna and footprint - Near and Far range points; Slant and Ground Swath - Slant and ground range resolution - Real Aperture Radar - Synthetic Aperture Principle	Slides: 24_SAR_fundamentals https://youtu.be/YsuInZE_4aY
65-66 GNSS #09	30/11/2022 Aula 9 PL	12:00-14:00	- Pseudorange Error Budget for PPS and SPS - Accuracy as DOP X UERE - Navigation performance parameters - Improving accuracy, availability improving DOP & UERE - Local area Integrity and error reduction principle	Slides: 35_GNSS_performance https://youtu.be/NDuucBoMjPs
67-68	01/12/2022 Room 32	10:00-12:00	- Distribution function of Gaussian r.v. - Error function and its complementary - Probability of being in an interval for Gaussian r.v. - Interval probability of +-n sigma around the mean and their inverse	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part2 https://youtu.be/vu_iMaDd1i0
69-70	02/12/2022 Room 40	12:00-14:00	- Multidimensional random vectors: distribution function, joint PDF, conditional probabilities - Mixed moments of different orders, correlation and covariance - The n-dimensional Gaussian: mean vector and covariance matrix	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part2 https://youtu.be/jkFkp4AgaB4
71-72	06/12/2022 Room 12	13:00-15:00	- Maximum synthetic aperture and azimuth resolution - Spotlight vs. STRIPMAP mode and their acquisition times - Doppler approach; Doppler bandwidth and minimum PRF for the azimuth spectrum sampling - Chirp in azimuth: duration, Bandwidth and slope	Slides: 24_SAR_fundamentals https://youtu.be/GYLRSGHTfqg
73-74 GNSS #10	07/12/2022 Aula 9 PL	12:00-14:00	- Local Area DGPS principle - Providing Integrity and Continuity by exploiting the monitoring reference station - Pseudorange error removal - Removal of ephemeris prediction equivalent error - problems for the extension to wide area DGPS	Slides: 35_GNSS_performance https://youtu.be/zADuI3hTQpo

	08/12/2022		- Immacolata	
75-76	09/12/2022 Room 40	12:00-14:00	- Up-down-conversion - DAC filtering and filtering + ADC - Digital modulation Mapping - Amplifiers operating in nonlinear region - Constant envelope modulations - Mapping for M-QAM, M-PSK, M- APSK - Error probability for coherent modulations: BPSK	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part3 https://youtu.be/Ij2aFutRbk0
77-78	13/12/2022 Room 12	13:00-15:00	- Interpretation of the azimuth Chirp matched filter as near-range antenna focusing - Exact phase history and quadratic phase approximation - Change of azimuth chirp slope with range - SAR image focusing techniques - RCM and its correction	Slides: 24_SAR_fundamentals https://youtu.be/JUmQhUwH7TI
79-80 GNSS #11	14/12/2022 Aula 9 PL	12:00-14:00	- GNSS Position Error Covariance matrix - DOP parameters - Positioning accuracy in 1D	Slides: 36_GNSS_accuracy https://youtu.be/F2oFQNOA-Nw
	15/12/2022 Room 32	10:00-12:00	- Lecture postponed to 19/12 for the event: "Seconda Giornata Nazionale dello Spazio: Sapienza ricorda il Prof. Carlo Buongiorno"	
81-82 GNSS #12	16/12/2022 Room 40	12:00-14:00	- 2D and 3D Gaussian PDF characteristics - 2D and 3D regions with High PDF values - GNSS Positioning accuracy in 2D & CEP - Probability ellipse and its derivation - GNSS Positioning accuracy in 3D & SEP - Probability ellipsoid and its derivation	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part2 35_GNSS_performance https://youtu.be/LLI0g5TMt18
83-84	19/12/2022 Room DIET 09 (adjacent to Room 9)	10:00-12:00	- Bit error rate for QPSK, M-QAM, M-PSK, M- APSK - Effect of rain on the uplink and downlink - Global link budget design	Slides: 04_Payload_Continuous_Probability_and_BER_v2_part3 05_Payload_ACM_SatTV_and_Internet_v3 https://youtu.be/alY7-E8iCe0
	20/12/2022 Small-Fresco's Cloister Lecture Room	12:00	Seminar by Thales Alenia Space Italy c/o Small- Fresco's Cloister Lecture Room	
85-86	20/12/2022 Lecture Room DIET 206 Room 12 PL	13:00-15:00	- Range and Doppler ambiguity - Large multimode SAR - High Resolution Wide Swath SAR - Small SAR satellite formations - Moving targets	Slides: 24_SAR_fundamentals (audio/video was not recorded – cause is unknown)
89-90 GNSS #13	21/12/2022 Aula 9 PL	12:00-14:00	- WADGPS - Galileo History - Galileo Integrity - Galileo GPS interoperability, - Galileo Signals In Space	Slides: 35_GNSS_performance 37_GNSS_GALILEO https://youtu.be/4yrDoom4Jn4

			- Galileo Services	
89-90	22/12/2022 Room 32	10:00- 12:00	- The evolution of Satellite TV Broadcast: Tx chain, transponder, RX chain, beams usage - Adaptive Coding and Modulation to contrast rain - The evolution of Satellite Internet: Tx chain, transponder, RX chain, beams usage	05_Payload_ACM_SatTV_and_Internet_v3 https://youtu.be/JuS3WE0GqJo