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A Real-time Pose Estimation Application for Simple Dances

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A Capstone Project on Operational Technologies
Presented to the Faculty of the
Department of Electronics and Computer Engineering
Gokongwei College of Engineering
De La Salle University

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In Partial Fulfillment of the
Operational Technologies

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by

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ELLAR Gerald Antonio P.
MAHAIT Hans

19

September, 2025

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ABSTRACT

21 Keep your abstract short by giving the gist/nutshell of your capstone project on operational
22 technologies. Use the following checklist questions to help you in crafting your abstract.

23 Did you briefly state what you intend to do?

24 Did you concisely discuss the problem statement?

25 Did you tersely mention the objectives in general terms?

26 Did you succinctly describe the methodology for the target audience?

27 Did you strongly describe your significant results and your conclusions?

28 *Index Terms*—Dance, Pose Estimation, Real-time, OpenPose .

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142 **ABBREVIATIONS**

143	AC	Alternating Current.....	73
144	CSS	Cascading Style Sheet	73
145	HTML	Hyper-text Markup Language	73
146	XML	eXtensible Markup Language	73

NOTATION

148	$ \mathcal{S} $	the number of elements in the set \mathcal{S}	75
149	\emptyset	the set with no elements	75
150	$h(t)$	impulse response	65
151	\mathcal{S}	a collection of distinct objects	75
152	\mathcal{U}	the set containing everything	75
153	$x(t)$	input signal represented in the time domain	65
154	$y(t)$	output signal represented in the time domain	65
155	Throughout this capstone project on operational technologies, mathematical notations conform to ISO 80000-2 standard, e.g., variable names are printed in italics, the only exception being acronyms like, e.g., SNR, which are printed in regular font. Constants are also set in regular font like j . Standard functions and operators are also set in regular font, e.g., in $\sin(\cdot)$, $\max\{\cdot\}$. Commonly used notations are t , f , $j = \sqrt{-1}$, n and $\exp(\cdot)$, which refer to the time variable, frequency variable, imaginary unit, n th variable, and exponential function, respectively.		
156			
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Chapter 1

181

INTRODUCTION

182 **1.1 Background of the Study**

183 Classical CV approaches used skin color segmentation, contour analysis, optical flow,
184 and handcrafted descriptors (HOG, motion history images) to detect and classify ges-
185 tures. Despite being simple and interpretable, those methods struggle with background
186 variation and scale. The deep-learning era replaced handcrafted features with CNNs that
187 learn hierarchical visual features directly from image data, yielding much higher accuracy
188 for static hand pose and short-sequence recognition tasks. Many recent capstone and
189 journal implementations pair OpenCV (for capture/preprocessing) with CNNs built and
190 trained in TensorFlow/PyTorch to recognize a fixed vocabulary of gestures in real time.
191 These hybrid pipelines are practical for capstone projects because OpenCV handles effi-
192 cient frame processing while CNNs provide generalization across users and backgrounds.
193 (<https://PMC8321080/>)

194 Instead of classifying raw images, several high-performance systems first extract skeletal
195 landmarks (e.g., MediaPipe's 21-point hand model) and feed those coordinates to a classifier
196 (small CNN, MLP, or temporal model like LSTM). Landmark-based pipelines reduce
197 sensitivity to background and scale and make models smaller and faster, which is ideal
198 for mobile or AR deployment. Markerless commercial devices such as the Leap Motion
199 Controller and Ultraleap cameras provide very accurate 3D joint data using IR illumination
200 and multi-camera setups; those give superior fidelity but add hardware cost and integration
201 work. For a capstone aiming at broad deployability, a practical approach is to prototype
202 with MediaPipe + OpenCV + CNN (or lightweight temporal model) and consider Ultraleap
203 integration later for high-precision installations. (<https://arxiv.org/abs/2006.10214>)

204 1.2 Prior Studies

205 MediaPipe Hands (Zhang et al., Google / arXiv; MediaPipe docs). MediaPipe Hands
206 presents a two-stage on-device pipeline (palm detector + hand-landmark regressor) that
207 extracts 21 hand landmarks from a single RGB frame and runs in real time on mobile
208 GPUs; the architecture and open implementation are widely used as a practical basis for
209 gesture recognition because they offer compact, robust landmark outputs that are easier
210 to classify than raw images. This work is especially relevant to mobile or cross-platform
211 deployment without extra hardware. (<https://arxiv.org/abs/2006.10214>) Ultraleap / Leap
212 Motion surveys and reviews. Reviews and vendor docs show that Ultraleap's IR stereo
213 cameras and LED illumination give very precise 3D joint tracking and low latency, making
214 them popular for VR/installation work; academic comparisons find Leap/Ultraleap and
215 MediaPipe are both capable, with trade-offs in precision versus hardware requirements.
216 Ultraleap or similar IR camera hardware is a practical choice for professional installa-
217 tion quality (amusement park kiosk, VR attraction). (docs.ultraleap.com) Sign-language
218 gesture recognition studies (landmark + CNN/LSTM). ASL and other sign recognition
219 papers demonstrate that combining landmark features (from MediaPipe or depth sensors)
220 with temporal models (LSTM/CNN temporal stacks) yields state-of-the-art results for
221 complex hand sequences. These studies emphasize the importance of considering variable
222 visibility conditions as spellcasting often requires temporal tracing (drawing shapes), and
223 not just static poses. This also provides insight into dataset design and labeling strategies.
224 (<https://arxiv.org/html/2406.03729v1>) A comparative study of advanced technologies and
225 methods in hand gesture analysis and recognition systems (Rahman et.al, 2025) Hand
226 gesture recognition is advancing as a key technology for human–machine interaction. This

study reviews both non-vision (e.g., sensor-based) and vision-based approaches, examining tools such as hidden Markov models, finite state machines, color modeling, naive Bayes, deep networks, histogram features, and fuzzy clustering. Methods are categorized into detection, tracking, and recognition phases, with comparisons across static and dynamic gestures. The review highlights current technologies, their advantages and limitations, and identifies directions for future research. Hand Gesture Recognition Based on Computer Vision: A Review of Techniques (Oudah, Al-Naji, Chahl, 2020) Hand gestures, as a form of nonverbal communication, are applied in fields such as HCI, assistive communication, robotics, home automation, and healthcare. Research spans sensor-based and vision-based methods, with gestures categorized as static, dynamic, or hybrid. This paper reviews literature on gesture recognition, comparing techniques in terms of segmentation, classification, datasets, gesture types, camera use, detection range, and performance. It provides a comprehensive overview of methods, their merits and limitations, and potential applications.

1.3 Problem Statement

Immersive interactive systems in gaming, AR, amusement parks, and accessibility still rely heavily on handheld controllers, touchscreens, or specialized hardware that break immersion, add cost, or exclude users with differing motor abilities. Markerless, camera-based hand-gesture recognition promises touchless, expressive input suitable for “magical” metaphors (casting spells, tracing runes) that are intuitive and socially engaging. However, real-world deployment is challenged by variable lighting, occlusion, noisy backgrounds, and latency. These problems make accuracy and robustness the central obstacles for any spell-

249 casting CV system. Modern solutions that combine real-time hand-lmark extraction and
250 convolutional neural networks (CNNs) have narrowed the gap, but careful design is required
251 to meet the high level competency goals for responsiveness, cross-platform deployment, and
252 accessibility. (<https://pmc.ncbi.nlm.nih.gov/articles/PMC8321080/>) A persuasive problem
253 statement from a contextualized and intended-audience-awareness perspective consists of:

254 1. PS1: description of the ideal scenario for your intended audience

- 255 • Describe the goals, desired state, or the values that your audience considers
256 important and that are relevant to the problem.

257 2. PS2: reality of the situation

- 258 • Describe a condition that prevents the goal, state, or value discussed in PS1
259 from being achieved or realized at the present time.
260 • It is imperative to make the audience feel the pain point.

261 3. PS3: consequences for the audience

- 262 • Using specific details, show how the situation contains a little promise of
263 improvement unless something is done.

264 After the above-mentioned items, succinctly describe your solution. Please avoid describing
265 your entire solution here since you will articulate and elucidate it by showing what you want
266 to achieve through your objectives, and how you will make it through your methodology.
267 A well-constructed problem statement will convince your audience that the problem is real
268 and worth having you solve it.

269 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
270 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
271 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
272 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
273 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
274 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
275 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
276 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
277 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

278 **1.4 Objectives and Deliverables**

279 Your objectives are the states that you desire to achieve in solving the problem. The general
280 objective is the main state to be achieved whereas the specific ones are sub-states to be
281 achieved.

282 **1.4.1 General Objective (GO)**

283 GO: To Morbi quis dolor. ;

284 **1.4.2 Specific Objectives (SOs)**

285 • SO1: To implement a real-time pipeline that captures camera frames, extracts ro-
286 bust hand features (landmarks or processed images), and classifies gestures into a
287 configurable spell vocabulary with low latency (30 fps target) and high accuracy;;

- 288 • SO2: To make the model robust to lighting, background clutter, and user variation
 289 through data augmentation and landmark-based representations ;
- 290 • SO3: To design the system to be deployable across desktop, mobile, and simple AR
 291 setups using cross-platform libraries (OpenCV, MediaPipe, TensorFlow/TensorFlow
 292 Lite) ;
- 293 • SO4: To make the interaction ergonomically accessible by supporting alternative
 294 gestures and calibration for users with different ranges of motion ;
- 295 • SO5: On UX side, to make spells feel immediately meaningful (clear mapping
 296 between motion and effect), provide instant feedback when a spell is recognized, and
 297 allow easy extension of the spell set. ;

298 **1.4.3 Expected Deliverables**

299 Table 1.1 shows the outputs, products, results, achievements, gains, realizations, and/or
 300 yields of the Capstone Project on Operational Technologies.

TABLE 1.1 EXPECTED DELIVERABLES PER OBJECTIVE

Objectives	Expected Deliverables
GO: To Morbi quis dolor.	:

301 **1.5 Significance of the Study**

302 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
 303 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec

304 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
305 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
306 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
307 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
308 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
309 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
310 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

311 **1.5.1 Technical Benefit**

312

313 1. First itemtext

314 2. Second itemtext

315 3. Last itemtext

316 4. First itemtext

317 5. Second itemtext

318 **1.5.2 Social Impact**

319

320 1. First itemtext

321 2. Second itemtext

322 3. Last itemtext

323 4. First itemtext

324 5. Second itemtext

325 **1.5.3 Environmental Welfare**

326

327 1. First itemtext

328 2. Second itemtext

329 3. Last itemtext

330 4. First itemtext

331 5. Second itemtext

332 **1.6 Assumptions, Scope, and Delimitations**

333 **1.6.1 Assumptions**

334 1. ...;

335 2. ...;

336 3. ...;

337 **1.6.2 Scope**

338 1. ...;

339 2. ...;

340 3. ...;

341 **1.6.3 Delimitations**

342 1. ...;

343 2. ...;

344 3. ...;

345 **1.7 Description and Methodology of the Capstone**

346 **Project on Operational Technologies**

347 1. Phase 1: Model Development serves a precursor for Phase 2 wherein the specifics
348 of the model, libraries, and environment to use are defined. In total, Phase 1 would
349 last 4 weeks spanning from week 4 to 7. The bulk of the research for the project
350 would be carried out during this phase. The dataset to be used for training would be
351 collected during this phase as well.

352 2. Phase 2: Model Training consists of training the model using the dataset collected
353 in the previous phase. This phase will largely consist of testing and improving the
354 resulting model. Tests would be conducted using the group members as dancers.

355 This phase also includes the optimization of the model for real-time detection simul-
356 taneously with the music. In total, this phase would last 4 weeks spanning from week
357 8 to 11.

358 3. Phase 3: UI/EX Development consists of the integration of the trained model with
359 a user interface. Once integrated final testing and refinement of the final program
360 would be carried out. The final output would be presented as well during this phase
361 along with the finalization of the documentation. This phase would last for 3 weeks
362 spanning from week 11 to 13

363 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
364 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
365 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
366 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
367 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
368 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
369 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
370 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
371 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Real-time Pose Estimation App for Dancing

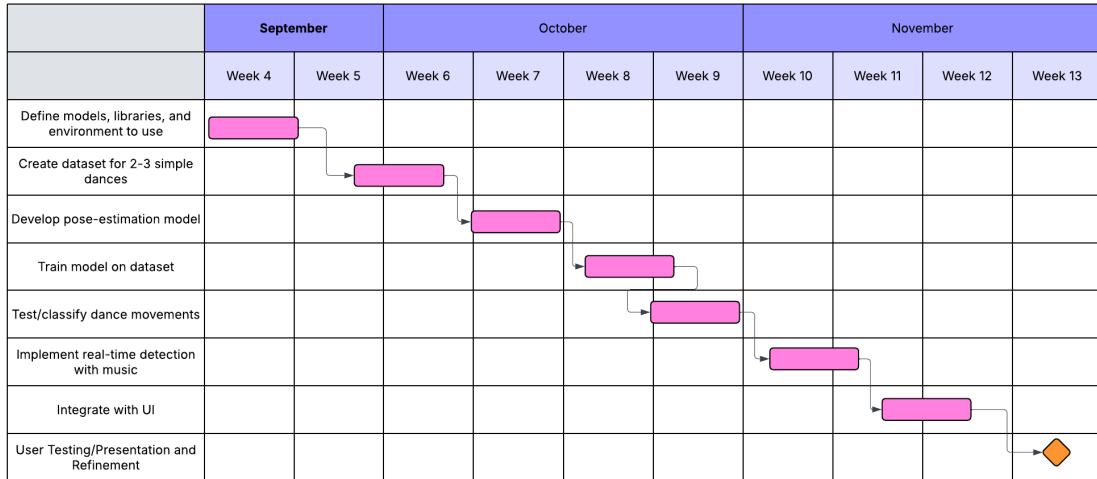


Fig. 1.1 Milestone Gantt Chart for Real-time Pose Estimation Dance Software

372 **1.8 Estimated Work Schedule and Budget**

373 **1.8.1 Milestones and Gantt Chart**

374 **1.8.2 Budget**

375 Given that the capstone project largely consists of software, apart from the use of a laptop
 376 for both programming, as well as actual implementation and usage of the dance program,
 377 the only expense to consider would be for that of a Webcam, which is already owned.

TABLE 1.2 OPERATIONAL FINANCIAL PLAN

Item	Price
Webcam	P1,850
Total	P1,850

378 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.

379 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
380 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
381 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
382 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
383 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
384 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
385 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
386 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

387 **1.9 Overview of the Capstone Project on Operational
388 Technologies**

389

Chapter 2

390

LITERATURE REVIEW

391 It is to be noted that each subsection in this chapter should discuss in narrative form
392 each table that is presented in order to point out to the reader what the author(s) intend to
393 convey.

394 **2.1 Existing Work**

395 Cite and summarize here relevant and significant literature (dissertations, theses, journals,
396 patents, notable conference papers) through a table and descriptions to prove that no one
397 has done your work yet and/or that your work is not a duplication of existing ones. Your
398 focus here is what has *been done*.

399 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
400 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
401 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
402 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
403 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
404 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
405 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
406 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
407 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

408 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
409 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
410 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
411 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
412 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla

413 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
414 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
415 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
416 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

417 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
418 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
419 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
420 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
421 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
422 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
423 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
424 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
425 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

426 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
427 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
428 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
429 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
430 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
431 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
432 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
433 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
434 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

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444 **2.2 Lacking in the Approaches**

445 You can summarize the weaknesses of existing approaches by a tabular comparison of the
446 literature. Your focus here is what has *not been done*, i.e. what features were missed, what
447 solutions were not considered, what the demerits are, etc. Through these items, you then
448 can introduce the necessity for doing your proposed solution.

449 It is to be noted that the degree of novelty for undergraduate thesis is lower than those
450 for graduate school. If a Ph.D. dissertation/thesis has a high degree of novelty and that for
451 an undergraduate is low, then a master's thesis is somewhere between the two.

452 Briefly include here the following in order to remind the reader why you are highlighting
453 the weaknesses of the solutions of existing literature.

- 454
- mentioning the problem
 - showing how your solution is better (can be better (for proposals))

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2. Literature Review

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501 **2.3 Summary**

502 Provide the gist of this chapter such that it reflects the contents and the message.

503

Chapter 3

504

THEORETICAL CONSIDERATIONS

3. Theoretical Considerations

505 Before starting the first section, provide an overview of the purpose of this chapter and
506 its contents, and how they are relevant to your methodology. Discuss in this chapter the
507 relevant theories and concepts that should support your proposed solutions.

508 This chapter is for providing the context to your panelist/reader. It is actually an
509 expanded form of the Background of the Study that you have put in Chapter 1.

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3. Theoretical Considerations

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Fig. 3.1 A quadrilateral image example.

555 **3.1 Summary**

556 Provide the gist of this chapter such that it reflects the contents and the message.

557

Chapter 4

558

DESIGN CONSIDERATIONS

559 Before starting the first section, provide an overview of the purpose of this chapter and
560 its contents, and how they are relevant to your methodology.

561 Your primary goal in the Design Considerations chapter is to describe to your pan-
562 elist/readers the key topics that fall further under Theoretical Considerations, but should
563 be placed here instead since they are geared towards your Methodology. These key topics
564 are those that you have directly adopted in making your solution/methodology. You can
565 think of the connection of the Design Considerations chapter to the Theoretical Considera-
566 tions chapter in this way: if your Theoretical Considerations chapter serves as the main
567 foundation of a building, then the Design Considerations chapter functions as the columns.

568 The Design Considerations chapter is an avenue for explaining why you considered
569 the topics here for your proposed methodology. This chapter is different from your
570 methodology, because topics you discuss here are already accepted as part of the body of
571 knowledge, and may have not been developed by you.

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4. Design Considerations

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617 **4.1 Standards**

618 Standards are essential for successful projects and impactful research. They provide a
619 common framework and ensure consistency, quality, and safety across various disciplines.
620 By adhering to established standards, your work becomes more reliable, interoperable, and
621 valuable in real-world applications. Standards also demonstrate your understanding of
622 industry best practices and enhance the credibility of your research.

623 To effectively integrate standards into your project, begin by identifying relevant stan-
624 dards related to your specific field. Thoroughly research and understand the requirements
625 and guidelines outlined within these standards. Align your project objectives and method-
626 ologies to meet or exceed these standards. Document your use of standards in this section,
627 including how and why specific standards were chosen. Finally, evaluate your results
628 against the established standards, justifying any deviations from the norm with sound

629 reasoning and evidence.

630 **4.2 Summary**

631 Provide the gist of this chapter such that it reflects the contents and message.

632

Chapter 5

633

METHODOLOGY

634 Put an overview of the contents of chapter. Mention here your methodology flow
 635 through a figure and provide an overview of it and how your methodology achieves your
 636 objectives. How your methodology achieves each of your specific objectives is what
 637 your panelists/examiners will be looking for. Specify how your methodology achieves
 638 your general objective and specific objectives. A point-by-point comparison how your
 639 methodology achieves each of your specific objectives is expected in the final Capstone
 640 Project on Operational Technologies.

641 Also make sure that you refer clearly to the chapters on the Literature Review, Theoretical
 642 Considerations, and Design Considerations showing how your methodology ties with
 643 those that you have discussed in those chapters.

644 Make an overview of the contents of the chapter. Put here your methodology flow
 645 through a figure and provide an overview of it.

646 In summative form, Table 5.1 indicates the approaches, designs, modes, processes,
 647 programs, techniques, and/or ways that the Capstone Project on Operational Technologies-
 648 reaches the objectives.

TABLE 5.1 SUMMARY OF METHODS FOR REACHING THE OBJECTIVES

Objectives	Methods	Locations
GO: To Morbi quis dolor.	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

Continued on next page

5. Methodology

Continued from previous page

Objectives	Methods	Locations
SO1: To implement a real-time pipeline that captures camera frames, extracts robust hand features (landmarks or processed images), and classifies gestures into a configurable spell vocabulary with low latency (30 fps target) and high accuracy;	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32
SO2: To make the model robust to lighting, background clutter, and user variation through data augmentation and landmark-based representations	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32
SO3: To design the system to be deployable across desktop, mobile, and simple AR setups using cross-platform libraries (OpenCV, Mediapipe, TensorFlow/TensorFlow Lite)	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32

Continued on next page

Continued from previous page

Objectives	Methods	Locations
SO4: To make the interaction ergonomically accessible by supporting alternative gestures and calibration for users with different ranges of motion	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32
SO5: On UX side, to make spells feel immediately meaningful (clear mapping between motion and effect), provide instant feedback when a spell is recognized, and allow easy extension of the spell set.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32

649 5.1 Implementation

650 Summarize the process used to create/set-up the work with an explanation of such process,
 651 instruments, and materials that you used if any. If the description is lengthy, use condensed
 652 bullet points.

653 *Rule of thumb:* Implementation is how you made your work; (keywords: implemented,
 654 created, made, soldered, programmed, etc.).

655 If you wrote a program or made a simulation, you must state how the program or
 656 simulation functions in this section. An algorithm or a pseudocode as shown in Table L.2
 657 is a good example.

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5. Methodology

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703 **5.2 Evaluation**

704 Describe the procedures for evaluating the correct behavior and outcome of your work,
705 including what information you need to gather and how you will obtain or measure it.

706 *Rule of thumb:* Evaluation is how you tested your work; (keywords: measured, tested,
707 compared, simulated, etc.).

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753 **5.3 Summary**

754 Provide the gist of this chapter such that it reflects the contents and the message.

755

Chapter 6

756

RESULTS AND DISCUSSIONS

6. Results and Discussions

757 Show in this chapter proofs why your proposed solution works. However, presenting
758 results ("It worked") without an appropriate explanation does not show thorough under-
759 standing. Aside from the data and results that you have obtained, and their explanation,
760 the discussion includes why components of your proposed solution work did or did not
761 work in accordance to what you described in the evaluation process, and how the proposed
762 solution performed and faired. Interpret the results and the reasons why they were obtained.
763 If your results are incorrect, apparent discrepancies from theory should be pointed out and
764 explained. In essence, what do the results mean? Citing existing publication can help you
765 compare your results and your explanations.

766 The next items below is not related to the description of this results and discussions
767 chapter, but serves as an opener for the L^AT_EXportion of this template.

768 Here is an example of a citation for ISO 80000-2 standard [?]. Another one is [?]
769 and [?].

770 In using this template, the user is expected to have a working knowledge of L^AT_EX. A
771 good introduction is in [?]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>. See the Appendix of document_guide.pdf for examples.

773 In aggregate form, Table 6.1 shows the outcomes and completions in applying the
774 methodology of the Capstone Project on Operational Technologiesper objective.

TABLE 6.1 SUMMARY OF RESULTS FOR ACHIEVING THE OBJECTIVES

Objectives	Results	Locations
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Continued on next page

6. Results and Discussions

Continued from previous page

Objectives	Results	Locations
GO: To Morbi quis dolor.	<ul style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO1: To implement a real-time pipeline that captures camera frames, extracts robust hand features (landmarks or processed images), and classifies gestures into a configurable spell vocabulary with low latency (30 fps target) and high accuracy;	<ul style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO2: To make the model robust to lighting, background clutter, and user variation through data augmentation and landmark-based representations	<ul style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

Continued on next page

6. Results and Discussions

Continued from previous page

Objectives	Results	Locations
SO3: To design the system to be deployable across desktop, mobile, and simple AR setups using cross-platform libraries (OpenCV, Mediapipe, TensorFlow/TensorFlow Lite)	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32
SO4: To make the interaction ergonomically accessible by supporting alternative gestures and calibration for users with different ranges of motion	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32
SO5: On UX side, to make spells feel immediately meaningful (clear mapping between motion and effect), provide instant feedback when a spell is recognized, and allow easy extension of the spell set.	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32

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6. Results and Discussions

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6. Results and Discussions

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820 **6.1 Summary**

821 Provide the gist of this chapter such that it reflects the contents and the message.

822

Chapter 7

823

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE DIRECTIVES

824

825 **7.1 Concluding Remarks**

826 In this Capstone Project on Operational Technologies, ...

827 Put here the main points that should be known and learned about the work topic.

828 Summarize or give the gist of the essential principles and inferences drawn from your

829 results.

830 **7.2 Contributions**

831 The interrelated contributions and supplements that have been developed by the author(s)

832 in this Capstone Project on Operational Technologies are listed as follows. Only those that

833 are unique to the authors' work are included.

834 • the ;

835 • the ;

836 • the ;

837 **7.3 Recommendations**

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7. Conclusions, Recommendations, and Future Directives

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7. Conclusions, Recommendations, and Future Directives

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883 **7.4 Future Prospects**

884 There are several prospects that may be extended for further studies. ... So the suggested
885 topics are listed in the following.

886 1. the

887 2. the

888 3. the

7. Conclusions, Recommendations, and Future Directives

889 Note that for ECE undergraduate theses, as per the directions of the thesis adviser,
890 Recommendations and Future Directives will be removed for the hardbound copy but will
891 be retained for database storage.

7. Conclusions, Recommendations, and Future Directives

892 ~~LAT~~E_X-comment this and the following texts after you have implemented them. See the
893 following references for helpful guides for the bibliography and script editing in general.
894 Note that the links might be unavailable, but the names can be searched in the Web.

- 895 1. IEEE Citation Reference: www.ieee.org/documents/ieeecitationref.pdf
896 2. IEEE Editorial Style manual: www.ieee.org/documents/style_manual.pdf
897 3. IEEE Abbreviations for Transactions, Journals, Letters, and Magazines: www.ieee.org/documents/trans_journal_names.pdf

899 Also in your BibTeX file, enclose letters or words that should all be in uppercase in curly
900 brackets. Example: IBM, Philippines, eXtensible Markup Language.

902
903

Chapter H

MEMBER SKILLSET IDENTIFICATION

TABLE H.1 TEAM MEMBERS' PROGRAMMING SKILLS

Member	Programming: Model Develop- ment	Programming: User Inter- face Design	Programming: Source Con- trol (GitHub)	Programming: Problem Solving & Optimization	Programming: Python Lan- guage Knowl- edge
Hans	Intermediate	Novice	Expert	Intermediate	Intermediate
Gerald	Intermediate	Basic	Novice	Intermediate	Intermediate
Nathan	Intermediate	Novice	Novice	Intermediate	Intermediate

904 **Chapter I**

905 **WORK BREAKDOWN**

906 **STRUCTURECAPSTONE PROJECT ON**

907 **OPERATIONAL TECHNOLOGIES**

I. Work Breakdown Structure Capstone Project on Operational Technologies

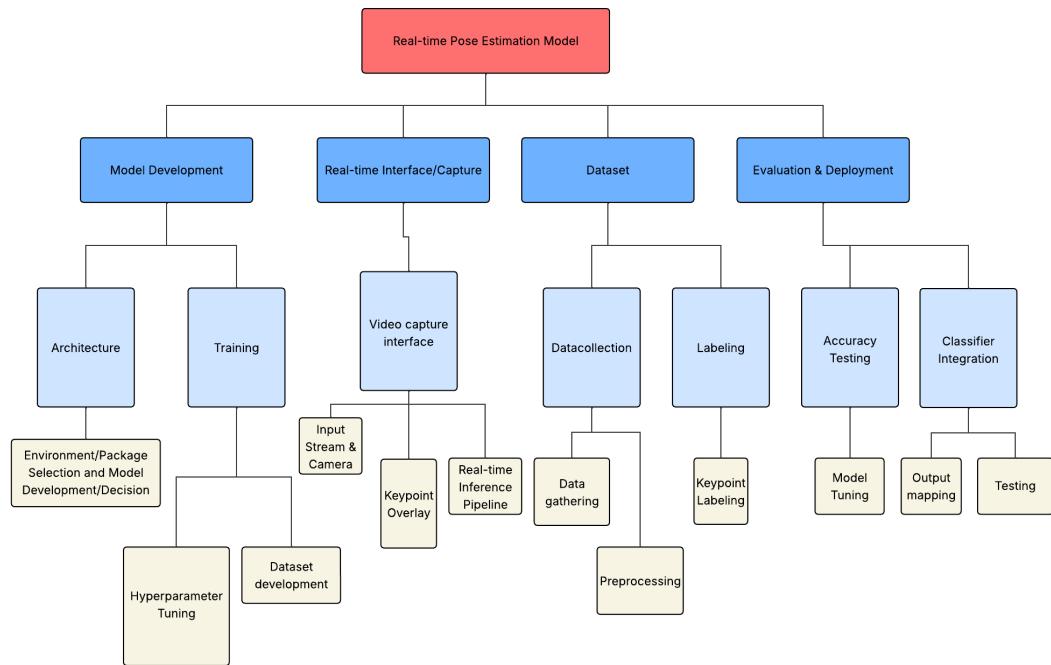


Fig. I.1 Work Breakdown Structure for Hans Capstone Project on Operational Technologies

I. Work Breakdown Structure Capstone Project on Operational Technologies

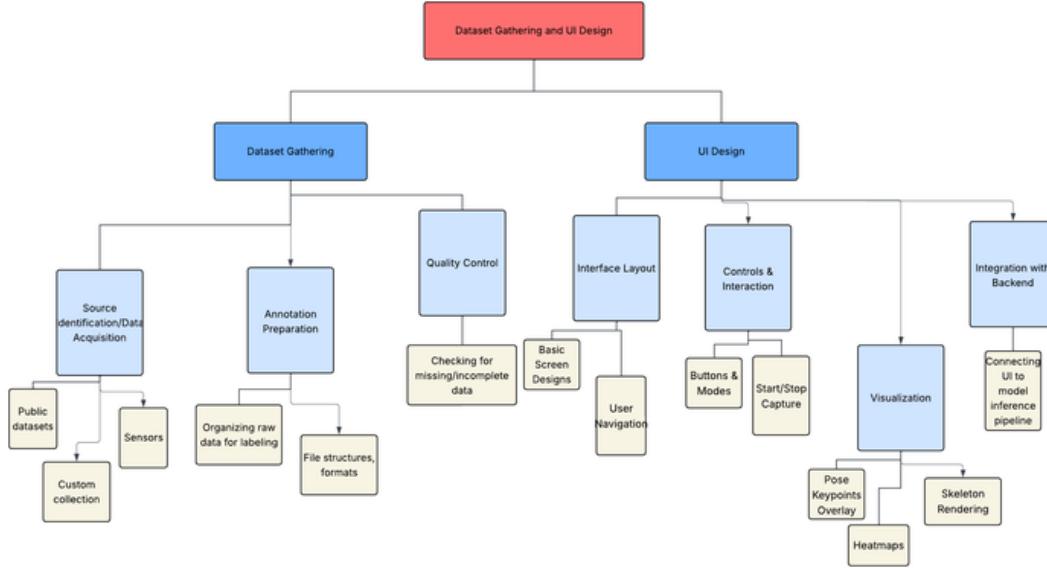


Fig. I.2 Work Breakdown Structure for Nathan Capstone Project on Operational Technologies

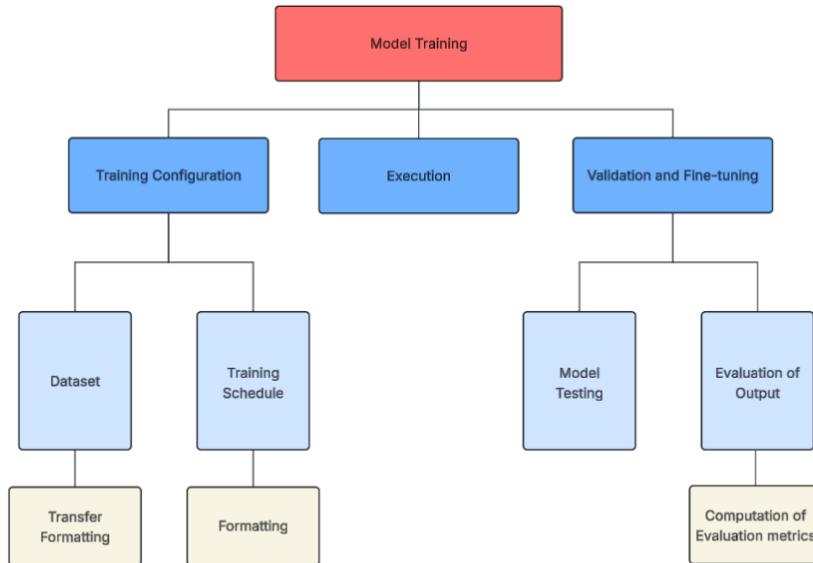


Fig. I.3 Work Breakdown Structure for Gerald Capstone Project on Operational Technologies

908
909

Chapter J REVISIONS TO THE PROPOSAL

J. Revisions to the Proposal

910 Make a table with the following columns for showing the summary of revisions to the
 911 proposal based on the comments of the panel of examiners.

- 912 1. Examiner
 913 2. Comment
 914 3. Summary of how the comment was addressed
 915 4. Locations in the document where the changes have been reflected

TABLE J.1 SUMMARY OF REVISIONS TO THE PROPOSAL

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Francisco D. Baltasar	<p>916 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>917 First itemtext</p> <p>918 Second itemtext</p> <p>919 Last itemtext</p> <p>920 First itemtext</p> <p>921 Second itemtext</p>	<p>922 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>923 First itemtext</p> <p>924 Second itemtext</p> <p>925 Last itemtext</p> <p>926 First itemtext</p> <p>927 Second itemtext</p>	<p>928 Sec. 5.1 929 on p. 32, 930 Sec. 5.2 931 on p. 35, 932 Fig. 3.1 on 933 p. 23</p>

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J. Revisions to the Proposal

Continued from previous page

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Amado			Sec. 5.1
Z. Hernandez			on p. 32,
			Sec. 5.2
			on p. 35,
			Fig. 3.1 on
			p. 23

Continued on next page

J. Revisions to the Proposal

Continued from previous page

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Jose Y. Alonzo	<p> Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p> Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p> Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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J. Revisions to the Proposal

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Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Mariana X. Mercado	<p> Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p> Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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J. Revisions to the Proposal

Continued from previous page

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Rafael W. Sison	<p>Dr. Rafael W. Sison's comment is a long, dense paragraph of placeholder text (Lorem ipsum) in English. It discusses various aspects of a document, such as the introduction of new concepts, the development of arguments, and the conclusion of sections. The text is intended to represent a real comment but is not specific to the context of the proposal.</p>	<p>Dr. Rafael W. Sison's response to the comment is also a long, dense paragraph of placeholder text (Lorem ipsum) in English. It provides a detailed summary of how the comment was addressed, likely involving multiple revisions and discussions. The response is comprehensive, covering all aspects of the comment.</p>	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

916
917

Chapter K REVISIONS TO THE FINAL

K. Revisions to the Final

918 Make a table with the following columns for showing the summary of revisions to the
 919 proposal based on the comments of the panel of examiners.

- 920 1. Examiner
 921 2. Comment
 922 3. Summary of how the comment has been addressed
 923 4. Locations in the document where the changes have been reflected

**TABLE K.1 SUMMARY OF REVISIONS TO THE CAPSTONE PROJECT ON
OPERATIONAL TECHNOLOGIES**

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Francisco D. Baltasar	<p>1. First itemtext</p> <p>2. Second itemtext</p> <p>3. Last itemtext</p> <p>4. First itemtext</p> <p>5. Second itemtext</p>	<p>1. First itemtext</p> <p>2. Second itemtext</p> <p>3. Last itemtext</p> <p>4. First itemtext</p> <p>5. Second itemtext</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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K. Revisions to the Final

Continued from previous page

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Amado Z. Hernandez	<p>1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext</p> <p>First itemtext Second itemtext Last itemtext First itemtext Second itemtext</p>	<p>1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext</p>	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
Dr. Jose Y. Alonzo	<p>1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p>1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext</p>	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23

Continued on next page

K. Revisions to the Final

Continued from previous page

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Mariana X. Mercado	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
Dr. Rafael W. Sison	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23

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925

Chapter L **USAGE EXAMPLES**

926 The user is expected to have a working knowledge of L^AT_EX. A good introduction is
 927 in [?]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>.

928 **L1 Equations**

929 The following examples show how to typeset equations in L^AT_EX. This section also shows
 930 examples of the use of `\gls{ }` commands in conjunction with the items that are in
 931 the `notation.tex` file. **Please make sure that the entries in `notation.tex` are
 932 those that are referenced in the L^AT_EX document files used by this Capstone Project on
 933 Operational Technologies. Please comment out unused notations and be careful with
 934 the commas and brackets in `notation.tex` .**

935 In (L.1), the output signal $y(t)$ is the result of the convolution of the input signal $x(t)$
 936 and the impulse response $h(t)$.

$$y(t) = h(t) * x(t) = \int_{-\infty}^{+\infty} h(t - \tau) x(\tau) d\tau \quad (\text{L.1})$$

937 Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \quad (\text{L.2})$$

$$\frac{1}{2} < \left\lfloor \mod \left(\left\lfloor \frac{y}{17} \right\rfloor 2^{-17|x| - \mod(\lfloor y \rfloor, 17)}, 2 \right) \right\rfloor, \quad (\text{L.3})$$

$$|\zeta(x)^3 \zeta(x+iy)^4 \zeta(x+2iy)| = \exp \sum_{n,p} \frac{3 + 4 \cos(ny \log p) + \cos(2ny \log p)}{np^{nx}} \geq 1 \quad (\text{L.4})$$

938

The verbatim L^AT_EX code of Sec. L1 is in List. L1.

Listing L.1: Sample L^AT_EX code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX. This
2 section also shows examples of the use of \verb| \gls{ } | commands
3 in conjunction with the items that are in the \verb| notation.tex |
4 file. \textbf{Please make sure that the entries in} \verb| notation.tex |
5 \textbf{| are those that are referenced in the \LaTeX \-
6 document files used by this \documentType. Please comment out
7 unused notations and be careful with the commas and brackets in} \-
8 \verb| notation.tex |.
9
10 In \eqref{eq:conv}, the output signal \gls{not:output_sigt} is the
11 result of the convolution of the input signal \gls{not:input_sigt}
12 and the impulse response \gls{not:ir}.
13
14 \begin{eqnarray}
15     y\left( t \right) = h\left( t \right) * x\left( t \right)=\int_{-\infty}^{+\infty}h\left( t-\tau \right)x\left( \tau \right) \mathrm{d}\tau
16 \label{eq:conv}
17 \end{eqnarray}
18 Other example equations are as follows.
19
20 \begin{eqnarray}
21     \left[ \frac{V_1}{I_1} \right] = \begin{bmatrix} A & B \\ C & D \end{bmatrix}
22 \label{eq:ABCD}
23 \end{eqnarray}
24
25 \begin{eqnarray}
26 \frac{1}{2} < \left\lfloor \mod{\left\lfloor \frac{y}{17} \right\rfloor}{2^{17}} \right\rfloor - \left\lfloor \mod{\left\lfloor y \right\rfloor}{17} \right\rfloor, 2 \right\rangle \right\rfloor,
27 \end{eqnarray}
28
29 \begin{eqnarray}
30 \left| \zeta(x)^3 \zeta(x + iy)^4 \zeta(x + 2iy) \right| = \exp \sum_{n,p} \frac{3 + 4 \cos(ny \log p) + \cos(2ny \log p)}{np^{nx}} \geq 1
31 \end{eqnarray}

```

939 L2 Notations

940 In order to use the standardized notation, the user is highly suggested to see the ISO 80000-2
 941 standard [?].

942 See https://en.wikipedia.org/wiki/Help:Displaying_a_formula and https://en.wikipedia.org/wiki/List_of_mathematical_symbols for L^AT_EX maths and other notations, respectively.

944 The following were taken from `isomath-test.tex`.

945 L2.1 Math alphabets

946 If there are other symbols in place of Greek letters in a math alphabet, it uses T1 or OT1
 947 font encoding instead of OML.

mathnormal	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathrm	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathbf	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, ff, fi, \mathbf{\beta}, ^!, \mathbf{v}, \mathbf{w}, 0, 1, 9$
mathsf	$\mathsf{A}, \mathsf{B}, \mathsf{\Gamma}, \mathsf{\Delta}, \mathsf{\Theta}, \mathsf{\Lambda}, \mathsf{\Xi}, \mathsf{\Pi}, \mathsf{\Sigma}, \mathsf{\Phi}, \mathsf{\Psi}, \mathsf{\Omega}, ff, fi, \mathsf{\beta}, ^!, \mathsf{v}, \mathsf{w}, 0, 1, 9$
mathtt	$\mathtt{A}, \mathtt{B}, \mathtt{\Gamma}, \mathtt{\Delta}, \mathtt{\Theta}, \mathtt{\Lambda}, \mathtt{\Xi}, \mathtt{\Pi}, \mathtt{\Sigma}, \mathtt{\Phi}, \mathtt{\Psi}, \mathtt{\Omega}, \uparrow, \downarrow, \mathfrak{B}, ^!, \mathtt{v}, \mathtt{w}, 0, 1, 9$

948 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

mathbfit	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \mathbf{\alpha}, \mathbf{\beta}, \mathbf{\pi}, \mathbf{\nu}, \mathbf{\omega}, \mathbf{v}, \mathbf{w}, \mathbf{o}, \mathbf{1}, \mathbf{9}$
mathsfit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, o, 1, 9$
mathsfbf	$\mathsf{A}, \mathsf{B}, \mathsf{\Gamma}, \mathsf{\Delta}, \mathsf{\Theta}, \mathsf{\Lambda}, \mathsf{\Xi}, \mathsf{\Pi}, \mathsf{\Sigma}, \mathsf{\Phi}, \mathsf{\Psi}, \mathsf{\Omega}, \mathsf{\alpha}, \mathsf{\beta}, \mathsf{\pi}, \mathsf{\nu}, \mathsf{\omega}, \mathsf{v}, \mathsf{w}, \mathsf{o}, \mathsf{1}, \mathsf{9}$

949 Do the math alphabets match?

950 $ax\alpha\omega ax\alpha\omega ax\alpha\omega \quad TC\Theta\Gamma TC\Theta\Gamma TC\Theta\Gamma$

951 L2.2 Vector symbols

952 Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot a$, while numeric ones (e.g.
 953 the zero vector) are bold upright, $a + 0 = a$.

954 L2.3 Matrix symbols

955 Symbols for matrices are boldface italic, too:¹ $A = E \cdot A$.

¹However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector F or the electrical field E .

956 **L2.4 Tensor symbols**

957 Symbols for tensors are sans-serif bold italic,

$$\boldsymbol{\alpha} = \mathbf{e} \cdot \mathbf{a} \iff \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

958 The permittivity tensor describes the coupling of electric field and displacement:

$$\mathbf{D} = \epsilon_0 \epsilon_r \mathbf{E}$$

959 L2.5 Bold math version

960 The “bold” math version is selected with the commands `\boldmath` or `\mathversion{bold}`

mathnormal	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathrm	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathbf	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathsf	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$
mathtt	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, ff, fi, \beta, ^!, v, w, 0, 1, 9$

961 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

mathbfit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathsfit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathsfbfit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$

962 Do the math alphabets match?

963 $a x \alpha \omega a x \alpha \omega a x \alpha \omega \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

964 L2.5.1 Vector symbols

965 Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot a$, while numeric ones (e.g.
966 the zero vector) are bold upright, $a + 0 = a$.

967 L2.5.2 Matrix symbols

968 Symbols for matrices are boldface italic, too:² $\Lambda = E \cdot A$.

969 L2.5.3 Tensor symbols

970 Symbols for tensors are sans-serif bold italic,

$$\alpha = e \cdot a \iff \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

971 The permittivity tensor describes the coupling of electric field and displacement:

$$D = \epsilon_0 \epsilon_r E$$

²However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector F or the electrical field E .

972 The verbatim L^AT_EX code of Sec. L2 is in List. L.2.

Listing L.2: Sample L^AT_EX code for notations usage

```

973
974 1 % A teststring with Latin and Greek letters::
975 2 \newcommand{\teststring}{%
976 3 % capital Latin letters
977 4 % A,B,C,
978 5 A,B,
979 6 % capital Greek letters
980 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
981 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
982 9 % small Greek letters
983 10 \alpha,\beta,\pi,\nu,\omega,
984 11 % small Latin letters:
985 12 % compare \nu, \omega, v, and w
986 13 v,w,
987 14 % digits
988 15 0,1,9
989 16 }
990 17
991 18
992 19 \subsection{Math alphabets}
993 20
994 21 If there are other symbols in place of Greek letters in a math
995 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
996 23
997 24 \begin{eqnarray*}
998 25 \mbox{\rm \textnormal} & & \teststring \\
999 26 \mbox{\rm \textit} & & \mathit{\teststring} \\
1000 27 \mbox{\rm \textrm} & & \mathrm{\teststring} \\
1001 28 \mbox{\rm \textbf} & & \mathbf{\teststring} \\
1002 29 \mbox{\rm \textsf} & & \mathsf{\teststring} \\
1003 30 \mbox{\rm \texttt} & & \mathtt{\teststring} \\
1004 31 \end{eqnarray*}
1005 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1006 33 italic.
1007 34 \begin{eqnarray*}
1008 35 \mbox{\rm \textbf\it} & & \mathbf\it{\teststring} \\
1009 36 \mbox{\rm \textsf\it} & & \mathsf\it{\teststring} \\
1010 37 \mbox{\rm \textsf\bf\it} & & \mathsf\bf\it{\teststring} \\
1011 38 \end{eqnarray*}
1012 39 %
1013 40 Do the math alphabets match?
1014 41 $
1015 42 \mathnormal {a x \alpha \omega}
1016 43 \mathbf {a x \alpha \omega}
1017 44 \mathsf {a x \alpha \omega}
1018 45 \quad
1019 46 \mathsfbf{T C \Theta \Gamma}
1020 47 \mathbf {T C \Theta \Gamma}
1021 48 \mathnormal {T C \Theta \Gamma}
1022 49 $
1023 50
1024 51 \subsection{Vector symbols}
1025 52

```

```

1027 53 Alphabetic symbols for vectors are boldface italic,
1028 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1029 55 while numeric ones (e.g. the zero vector) are bold upright,
1030 56  $\vec{a} + \vec{0} = \vec{a}$ .
1031 57
1032 58 \subsection{Matrix symbols}
1033 59
1034 60 Symbols for matrices are boldface italic, too:%
1035 61 \footnote{However, matrix symbols are usually capital letters whereas
1036 62 vectors
1037 63 are small ones. Exceptions are physical quantities like the force
1038 64 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%}
1039 65  $\mathbf{\Lambda} = \mathbf{E} \cdot \mathbf{A}$ 
1040 66
1041 67
1042 68 \subsection{Tensor symbols}
1043 69
1044 70 Symbols for tensors are sans-serif bold italic,
1045 71
1046 72 \[
1047 73   \text{tensorsym}{\alpha} = \text{tensorsym}{e} \cdot \text{tensorsym}{a}
1048 74   \quad \Longleftarrow \quad
1049 75   \alpha_{ijk} = e_{ijk} \cdot a_{kl}.
1050 76 \]
1051 77
1052 78
1053 79 The permittivity tensor describes the coupling of electric field and
1054 80 displacement: \[
1055 81  $\vec{D} = \epsilon_0 \text{tensorsym}{\epsilon}_{\text{r}} \vec{E}$ 
1056 82
1057 83
1058 84
1059 85 \newpage
1060 86 \subsection{Bold math version}
1061 87
1062 88 The ‘‘bold’’ math version is selected with the commands
1063 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1064 90
1065 91 \boldmath
1066 92   \begin{eqnarray*}
1067 93     \mathnormal{} & & \mathit{} \\
1068 94     \mathit{} & & \mathit{\mathit{teststring}} \\
1069 95     \mathrm{} & & \mathrm{\mathit{teststring}} \\
1070 96     \mathbf{} & & \mathbf{\mathit{teststring}} \\
1071 97     \mathsf{} & & \mathsf{\mathit{teststring}} \\
1072 98     \mathtt{} & & \mathtt{\mathit{teststring}} \\
1073 99   \end{eqnarray*}
1074 100   New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1075 101   italic.
1076 102   \begin{eqnarray*}
1077 103     \mathbf{fit}{} & & \mathbf{fit}{\mathit{teststring}} \\
1078 104     \mathsf{fit}{} & & \mathsf{fit}{\mathit{teststring}} \\
1079 105     \mathsf{fbfit}{} & & \mathsf{fbfit}{\mathit{teststring}}
1080 106   \end{eqnarray*}
1081 107 %
1082 108
1083 109 Do the math alphabets match?

```

```

1084 108      $
1085 109
1086 110 \mathnormal {a x \alpha \omega}
1087 111 \mathbf{fit} {a x \alpha \omega}
1088 112 \mathsf{fbfit}{a x \alpha \omega}
1089 113 \quad
1090 114 \mathsf{fbfit}{T C \Theta \Gamma}
1091 115 \mathbf{fit} {T C \Theta \Gamma}
1092 116 \mathnormal {T C \Theta \Gamma}
1093 117 $
1094 118
1095 119 \subsection{Vector symbols}
1096 120
1097 121 Alphabetic symbols for vectors are boldface italic,
1098 122 $ \vec{\lambda} = \vec{e}_1 \cdot \vec{a} $,
1099 123 while numeric ones (e.g. the zero vector) are bold upright,
1100 124 $ \vec{a} + \vec{0} = \vec{a} $.
1101 125
1102 126
1103 127
1104 128
1105 129 \subsection{Matrix symbols}
1106 130
1107 131 Symbols for matrices are boldface italic, too:%
1108 132 \footnote{However, matrix symbols are usually capital letters whereas
1109   vectors
1110 133 are small ones. Exceptions are physical quantities like the force
1111 134 vector $ \vec{F} $ or the electrical field $ \vec{E} $.%}
1112 135 }
1113 136 $ \mathbf{matrixsym}{\Lambda} = \mathbf{matrixsym}{E} \cdot \mathbf{matrixsym}{A} . $%
1114 137
1115 138
1116 139 \subsection{Tensor symbols}
1117 140
1118 141 Symbols for tensors are sans-serif bold italic,
1119 142
1120 143 \[
1121 144   \mathbf{tensorsym}{\alpha} = \mathbf{tensorsym}{e} \cdot \mathbf{tensorsym}{a}
1122 145   \quad \Longleftarrow \quad
1123 146   \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
1124 147 \]
1125 148
1126 149 The permittivity tensor describes the coupling of electric field and
1127 150 displacement: \[
1128 151   \vec{D} = \epsilon_0 \mathbf{tensorsym}{\epsilon}(\mathbf{r}) \cdot \vec{E} \]
1129 152 }
```

1131 L3 Abbreviation

1132 This section shows examples of the use of \LaTeX commands in conjunction with the
 1133 items that are in the `abbreviation.tex` and in the `glossary.tex` files. Please see
 1134 List. L.3. **To lessen the \LaTeX parsing time, it is suggested that you use `\acr{ }` only**
 1135 **for the first occurrence of the word to be abbreviated.**

1136 Again please see List. L.3. Here is an example of first use: alternating current (ac).
 1137 Next use: ac. Full: alternating current (ac). Here's an acronym referenced using `\acr`:
 1138 hyper-text markup language (html). And here it is again: html. If you are used to the
 1139 `glossaries` package, note the difference in using `\gls`: hyper-text markup language
 1140 (html). And again (no difference): hyper-text markup language (html). For plural use
 1141 `\glsp{}`. Here are some more entries:

- 1143 • extensible markup language (xml) and cascading style sheet (css).
- 1144 • Next use: xml and css.
- 1145 • Full form: extensible markup language (xml) and cascading style sheet (css).
- 1146 • Reset again.
- 1147 • Start with a capital. Hyper-text markup language (html).
- 1148 • Next: Html. Full: Hyper-text markup language (html).
- 1149 • Prefer capitals? Extensible markup language (XML). Next: XML. Full: extensible
 1150 markup language (XML).
- 1151 • Prefer small-caps? Cascading style sheet (css). Next: CSS. Full: cascading style
 1152 sheet (CSS).
- 1153 • Resetting all acronyms.
- 1154 • Here are the acronyms again:
- 1155 • Hyper-text markup language (HTML), extensible markup language (XML) and cas-
 1156 cading style sheet (CSS).
- 1157 • Next use: HTML, XML and CSS.
- 1158 • Full form: Hyper-text markup language (HTML), extensible markup language (XML)
 1159 and cascading style sheet (CSS).

- 1160 • Provide your own link text: style sheet.

1161 The verbatim L^AT_EX code of Sec. L3 is in List. L3.

Listing L.3: Sample L^AT_EX code for abbreviations usage

```

1 Again please see List.~\ref{lst:abbrv}. Here is an example of first use:
  \acr{ac}. Next use: \acr{ac}. Full: \gls{ac}. Here's an acronym
  referenced using \verb|\acr|: \acr{html}. And here it is again: \acr{html}.
  If you are used to the \texttt{glossaries} package, note
  the difference in using \verb|\gls|: \gls{html}. And again (no
  difference): \gls{html}. Here are some more entries:
2
3 \begin{itemize}
4
5   \item \acr{xml} and \acr{css}.
6
7   \item Next use: \acr{xml} and \acr{css}.
8
9   \item Full form: \gls{xml} and \gls{css}.
10
11  \item Reset again. \glsresetall{abbreviation}
12
13  \item Start with a capital. \Acr{html}.
14
15  \item Next: \Acr{html}. Full: \Gls{html}.
16
17  \item Prefer capitals? \renewcommand{\acronymfont}[1]{\
      \MakeTextUppercase{#1}} \Acr{xml}. Next: \acr{xml}. Full: \gls{xml
    }.
18
19  \item Prefer small-caps? \renewcommand{\acronymfont}[1]{\textsc{#1}} \
      \Acr{css}. Next: \acr{css}. Full: \gls{css}.
20
21  \item Resetting all acronyms.\glsresetall{abbreviation}
22
23  \item Here are the acronyms again:
24
25  \item \Acr{html}, \acr{xml} and \acr{css}.
26
27  \item Next use: \Acr{html}, \acr{xml} and \acr{css}.
28
29  \item Full form: \Gls{html}, \gls{xml} and \gls{css}.
30
31  \item Provide your own link text: \glslink{[textbf]css}{style}
32
33 \end{itemize}
```

L4 Glossary

This section shows examples of the use of `\gls{ }` commands in conjunction with the items that are in the `glossary.tex` and `notation.tex` files. Note that entries in `notation.tex` are prefixed with “`not:`” label (see List. L.4).

Please make sure that the entries in `notation.tex` are those that are referenced in the L^AT_EX document files used by this Capstone Project on Operational Technologies. Please comment out unused notations and be careful with the commas and brackets in `notation.tex`.

- are usually denoted by a bold capital letter, such as A . The (i, j) th element is usually denoted a_{ij} . I is the identity .
- A set, denoted as S , is a collection of objects.
- The universal set, denoted as U , is the set of everything.
- The empty set, denoted as \emptyset , contains no elements.
- is seen as the study of complete normed vector spaces, i.e., Banach spaces.
- The cardinality of a set, denoted as $|S|$, is the number of elements in the set.

The verbatim L^AT_EX code for the part of Sec. L4 is in List. L.4.

Listing L.4: Sample L^AT_EX code for glossary and notations usage

```

1 \begin{itemize}
2
3   \item \Glspl{matrix} are usually denoted by a bold capital letter,
        such as  $\mathbf{A}$ . The \gls{matrix}'s  $(i,j)$ th element is
        usually denoted  $a_{ij}$ . \Gls{matrix}  $\mathbf{I}$  is the
        identity \gls{matrix}.
4
5   \item A set, denoted as \gls{not:set}, is a collection of objects.
6
7   \item The universal set, denoted as \gls{not:universalSet}, is the
        set of everything.
8
9   \item The empty set, denoted as \gls{not:emptySet}, contains no
        elements.
10
11  \item \Gls{Functional Analysis} is seen as the study of complete
      normed vector spaces, i.e., Banach spaces.
12
13  \item The cardinality of a set, denoted as \gls{not:cardinality}, is
      the number of elements in the set.
14
15 \end{enumerate}

```

L5 Figure

This section shows several ways of placing figures. PDF^LA_TE_X compatible files are PDF, PNG, and JPG. Please see the `figure` subdirectory.

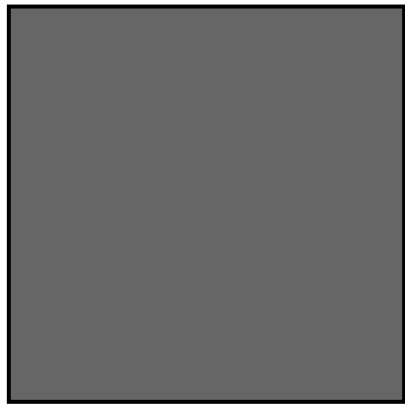


Fig. L.1 A quadrilateral image example.

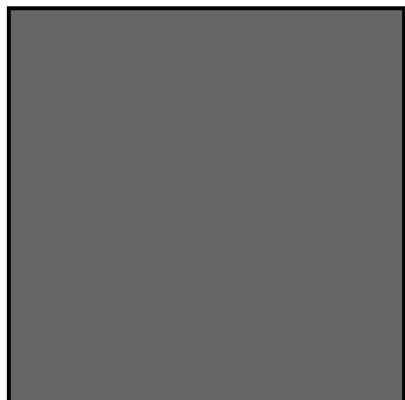
1181 Fig. L.1 is a gray box enclosed by a dark border. List. L.5 shows the corresponding
1182 \LaTeX code.

Listing L.5: Sample \LaTeX code for a single figure

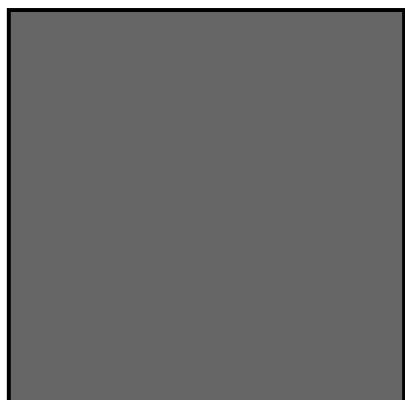
```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\ref{lst:onefig} shows the corresponding \LaTeX \ code.
10 \end{figure}
```



(a) A sub-figure in the top row.



(b) A sub-figure in the middle row.

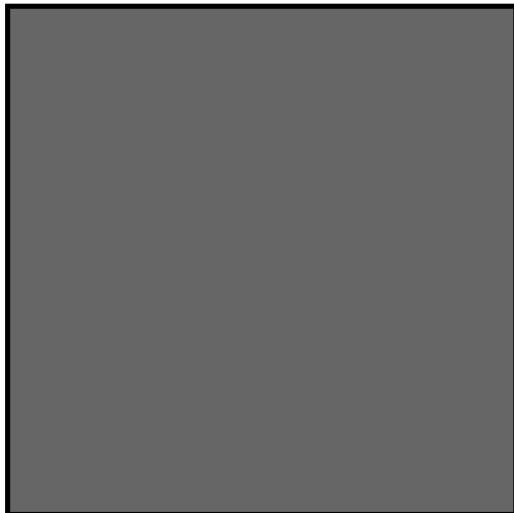


(c) A sub-figure in the bottom row.

Fig. L.2 Figures on top of each other. See List. L.6 for the corresponding L^AT_EX code.

Listing L.6: Sample L^AT_EX code for three figures on top of each other

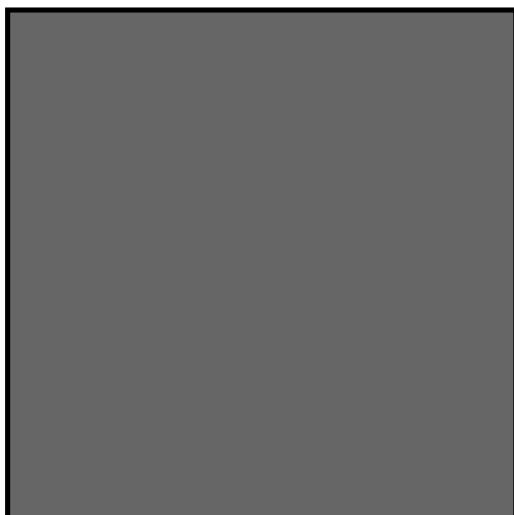
```
1 \begin{figure} [!htbp]
2   \centering
3   \subbottom[A sub-figure in the top row.]{%
4     \includegraphics [width=0.35\textwidth]{example_gray_box}
5     \label{fig:top}
6   }
7   \vfill
8   \subbottom[A sub-figure in the middle row.]{%
9     \includegraphics [width=0.35\textwidth]{example_gray_box}
10    \label{fig:mid}
11  }
12   \vfill
13  \subbottom[A sub-figure in the bottom row.]{%
14    \includegraphics [width=0.35\textwidth]{example_gray_box}
15    \label{fig:botm}
16  }
17  \caption{Figures on top of each other}
18  \label{fig:tmb}
19 \end{figure}
```



(a) A sub-figure in the upper-left corner.



(b) A sub-figure in the upper-right corner.



(c) A sub-figure in the lower-left corner.



(d) A sub-figure in the lower-right corner

Fig. L.3 Four figures in each corner. See List. L.7 for the corresponding L^AT_EX code.

Listing L.7: Sample L^AT_EX code for the four figures

```
1 \begin{figure} [!htbp]
2   \centering
3   \subbottom[A sub-figure in the upper-left corner.]{
4     \includegraphics[width=0.45\textwidth]{example_gray_box}
5     \label{fig:upprleft}
6   }
7   \hfill
8   \subbottom[A sub-figure in the upper-right corner.]{
9     \includegraphics[width=0.45\textwidth]{example_gray_box}
10    \label{fig:uppright}
11  }
12   \vfill
13   \subbottom[A sub-figure in the lower-left corner.]{
14     \includegraphics[width=0.45\textwidth]{example_gray_box}
15     \label{fig:lowerleft}
16  }
17   \hfill
18   \subbottom[A sub-figure in the lower-right corner.]{
19     \includegraphics[width=0.45\textwidth]{example_gray_box}
20     \label{fig:lowright}
21  }
22   \caption{Four figures in each corner. See List.\ref{lst:fourfigs} for
23     the corresponding \LaTeX \ code.}
24   \label{fig:fourfig}
25 \end{figure}
```

L6 Table

1183

1184 This section shows an example of placing a table (a long one). Table L.1 are the triples.

TABLE L.1 FEASIBLE TRIPLES FOR HIGHLY VARIABLE GRID

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

Continued on next page

Continued from previous page

Time (s)	Triple chosen	Other feasible triples
126270	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
129015	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
131760	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
134505	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
137250	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
139995	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
142740	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
145485	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
148230	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
150975	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
153720	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
156465	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
159210	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
161955	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
164700	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

1185

1186 List. L.8 shows the corresponding L^AT_EX code.

Listing L.8: Sample L^AT_EX code for making typical table environment

```

1188 1 \begin{center}
1189 2 {\scriptsize
1190 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
1191 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
1192 5 \grid} \\
1193 6 \hline
1194 7 \textbf{Time (s)} &
1195 8 \textbf{Triple chosen} &
1196 9 \textbf{Other feasible triples} \\
1197 10 \hline
1198 11 \endfirsthead
1199 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
1200 13 \hline
1201 14 \endhead
1202 15 \hline
1203 16 \textbf{Time (s)} &
1204 17 \textbf{Triple chosen} &
1205 18 \textbf{Other feasible triples} \\
1206 19 \hline
1207 20 \endhead
1208 21 \hline
1209 22 \multicolumn{3}{r}{\textit{Continued on next page}} \\
1210 23 \endfoot
1211 24 \hline
1212 25 \endlastfoot
1213 26 \hline
1214 27
1215 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
1216 29 \\
1217 30 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
1218 31 \\
1219 32 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1220 33 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1221 34 0) \\
1222 35 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1223 36 0) \\
1224 37 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1225 38 0) \\
1226 39 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1227 40 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1228 41 0) \\
1229 42 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1230 43 0) \\
1231 44 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1232 45 0) \\
1233 46 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1234 47 0) \\
1235 48 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1236 49 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1237 50 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1238 51 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1239 52
1240 53

```

L. Usage Examples

```

1241 43 | 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1242   0) \\
1243 44 | 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1244 45 | 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1245 46 | 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1246 47 | 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1247   0) \\
1248 48 | 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1249 49 | 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1250 50 | 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1251 51 | 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1252 52 | 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1253 53 | 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1254 54 | 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1255 55 | 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1256 56 | 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1257 57 | 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1258 58 | 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1259 59 | 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1260   0) \\
1261 60 | 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1262 61 | 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1263 62 | 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1264 63 | 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1265 64 | 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1266 65 | 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1267 66 | 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1268 67 | 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1269 68 | 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1270 69 | 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1271   1, 0) \\
1272 70 | 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1273 71 | 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1274 72 | 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1275 73 | 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1276 74 | 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1277   1, 0) \\
1278 75 | 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1279 76 | 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1280 77 | 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1281 78 | 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1282 79 | 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1283 80 | 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1284 81 | 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1285   1, 0) \\
1286 82 | 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1287 83 | 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1288 84 | 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1289 85 | 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1290 86 | 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1291 87 | 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1292 88 | 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1293 89 | \end{tabularx} \\
1294 90 | } \\
1295 91 | \end{center}

```

L7 Algorithm or Pseudocode Listing

Table L.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. L.9 shows the corresponding L^AT_EX code.

TABLE L.2 CALCULATION OF $y = x^n$

Input(s):	
n	: n th power; $n \in \mathbb{Z}^+$
x	: base value; $x \in \mathbb{R}^+$
Output(s):	
y	: result; $y \in \mathbb{R}^+$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```

1:  $y \Leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \Leftarrow 1/x$ 
4:    $N \Leftarrow -n$ 
5: else
6:    $X \Leftarrow x$ 
7:    $N \Leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:   if  $N$  is even then
11:      $X \Leftarrow X \times X$ 
12:      $N \Leftarrow N/2$ 
13:   else { $N$  is odd}
14:      $y \Leftarrow y \times X$ 
15:      $N \Leftarrow N - 1$ 
16:   end if
17: end while

```

Listing L.9: Sample L^AT_EX code for algorithm or pseudocode listing usage

```

1 \begin{table} [!htbp]
2   \caption{Calculation of $y = x^n$}
3   \label{tab:calcxn}
4   \footnotesize
5   \begin{tabular}{lll}
6     \hline
7     \hline
8     {\bfseries Input(s):} & & \\
9     $n$ & : & $n$th power; $n \in \mathbb{Z}^{+}$ \\
10    $x$ & : & base value; $x \in \mathbb{R}^{+}$ \\
11    \hline
12   {\bfseries Output(s):} & & \\
13   $y$ & : & result; $y \in \mathbb{R}^{+}$ \\
14   \hline
15   \hline
16   \\
17   \end{tabular}
18 }
19 \begin{algorithmic}[1]
20 \footnotesize
21   \REQUIRE $n \geq 0 \vee x \neq 0$ \\
22   \ENSURE $y = x^n$ \\
23   \STATE $y \Leftarrow 1$ \\
24   \IF{$n < 0$}
25     \STATE $X \Leftarrow 1 / x$ \\
26     \STATE $N \Leftarrow -n$ \\
27   \ELSE
28     \STATE $X \Leftarrow x$ \\
29     \STATE $N \Leftarrow n$ \\
30   \ENDIF \\
31   \WHILE{$N \neq 0$}
32     \IF{$N$ is even}
33       \STATE $X \Leftarrow X \times X$ \\
34       \STATE $N \Leftarrow N / 2$ \\
35     \ELSE[$N$ is odd]
36       \STATE $y \Leftarrow y \times X$ \\
37       \STATE $N \Leftarrow N - 1$ \\
38     \ENDIF \\
39   \ENDWHILE \\
40 }
41 \end{algorithmic}
42 \end{table}

```

L8 Program/Code Listing

1301 List L.10 is a program listing of a C code for computing Fibonacci numbers by calling the
 1302 actual code. Please see the `code` subdirectory.

Listing L.10: Computing Fibonacci numbers in C (`./code/fibo.c`)

```

1  /* fibo.c -- It prints out the first N Fibonacci
2   * numbers.
3   */
4
5  #include <stdio.h>
6
7  int main(void) {
8      int n;          /* Number of fibonacci numbers we will print */
9      int i;          /* Index of fibonacci number to be printed next */
10     int current;    /* Value of the (i)th fibonacci number */
11     int next;       /* Value of the (i+1)th fibonacci number */
12     int twoaway;    /* Value of the (i+2)th fibonacci number */
13
14     printf("How many Fibonacci numbers do you want to compute? ");
15     scanf("%d", &n);
16     if (n<=0)
17         printf("The number should be positive.\n");
18     else {
19         printf("\n\n\tI\tFibonacci(I)\n\t=====\\n");
20         next = current = 1;
21         for (i=1; i<=n; i++) {
22             printf("\t%d\t%d\\n", i, current);
23             twoaway = current+next;
24             current = next;
25             next = twoaway;
26         }
27     }
28 }
29
30 /* The output from a run of this program was:
31
32 How many Fibonacci numbers do you want to compute? 9
33
34 I  Fibonacci(I)
35 =====
36 1  1
37 2  1
38 3  2
39 4  3
40 5  5
41 6  8
42 7  13
43 8  21
44 9  34
45
46 */

```

1304 List. L.11 shows the corresponding L^AT_EX code.

Listing L.11: Sample L^AT_EX code for program listing

```
1 List.^{\ref{lst:fib_c}} is a program listing of a C code for computing  
Fibonacci numbers by calling the actual code. Please see the \verb|  
code | subdirectory.
```

L9 Referencing

Referencing chapters: This appendix is in Appendix L, which is about examples in using various \LaTeX commands.

Referencing sections: This section is Sec. L9, which shows how to refer to the locations of various labels that have been placed in the \LaTeX files. List. L.12 shows the corresponding \LaTeX code.

Listing L.12: Sample \LaTeX code for referencing sections

```
1 Referencing sections: This section is Sec.~\ref{sec:ref}, which shows
  how to refer to the locations of various labels that have been
  placed in the \LaTeX \ files. List.~\ref{lst:refsec} shows the
  corresponding \LaTeX \ code.
```

1311 Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem.
 1312 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1313 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1314 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1315 Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla
 1316 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1317 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1318 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1319 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1320 L9.1 A subsection

1321 Referencing subsections: This section is Sec.~\ref{sec:subsec}, which shows how to refer to a subsection.
 1322 List.~\ref{lst:refsub} shows the corresponding \LaTeX \ code.

Listing L.13: Sample \LaTeX code for referencing subsections

```
1 Referencing subsections: This section is Sec.~\ref{sec:subsec}, which
  shows how to refer to a subsection. List.~\ref{lst:refsub} shows the
  corresponding \LaTeX \ code.
```

1323 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1324 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1325 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1326 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1327 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1328 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1329 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1330 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1331 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1332 **L9.1.1 A sub-subsection**

1333 Referencing sub-subsections: This section is Sec. L9.1.1, which shows how to refer to a
 1334 sub-subsection. List. L.14 shows the corresponding L^AT_EX code.

Listing L.14: Sample L^AT_EX code for referencing sub-subsections

```
1 Referencing sub-subsections: This section is Sec.~\ref{sec:subsubsec},  

   which shows how to refer to a sub-subsection. List.~\ref{lst:  

   refsubsub} shows the corresponding \LaTeX \ code.
```

1335 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1336 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1337 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1338 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1339 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1340 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1341 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1342 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1343 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

L10 Citing

Citing bibliography content is done using BibTeX. It requires the creation of a BibTeX file (.bib extension name), and then added in the argument of `\bibliography{ }` . For each .bib file, separate them by a comma in the argument of `\bibliography{ }` without the extension name. Building your BibTeX file (references.bib) can be done easily with a tool called JabRef (www.jabref.org).

The following subsections are examples of citations.

L10.1 Books

• [?]

• [?]

• [?]

• [?]

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- 1390 • [?]
- 1391 • [?]
- 1392 • [?]
- 1393 • [?]
- 1394 • [?]
- 1395 • [?]

1396 **L10.2 Booklets**

1397 • [?]

1398 **L10.3 Proceedings**

1399 • [?]

1400 **L10.4 In books**

1401 • [?]

1402 • [?]

1403 • [?]

1404 • [?]

1405 • [?]

1406 • [?]

1407 • [?]

1408 • [?]

1409 • [?]

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1427 **L10.5 In proceedings**

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1435 **L10.6 Journals**

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1471 **L10.7 Theses/dissertations**

1472 • [?]

1473 • [?]

1474 • [?]

1475 • [?]

1476 • [?]

1477 • [?]

1478 • [?]

1479 **L10.8 Technical Reports and Others**

1480 • [?]

1481 • [?]

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1494 • [?]

1495 **L10.9 Miscellaneous**

1496 • [?]
1497 • [?]
1498 • [?]
1499 • [?]
1500 • [?]
1501 • [?]
1502 • [?]
1503 • [?]
1504 • [?]
1505 • [?]
1506 • [?]
1507 • [?]
1508 • [?]

1509 L11 Index

1510 For key words or topics that are expected (or the user would like) to appear in the Index, use
 1511 `index{key}` , where `key` is an example keyword to appear in the Index. For example,
 1512 Fredholm integral and Fourier operator of the following paragraph are in the Index.

1513 If we make a very large matrix with complex exponentials in the rows (i.e., cosine real
 1514 parts and sine imaginary parts), and increase the resolution without bound, we approach
 1515 the kernel of the Fredholm integral equation of the 2nd kind, namely the Fourier operator
 1516 that defines the continuous Fourier transform.

1517 List. L.15 is a program listing of the above-mentioned paragraph.

Listing L.15: Sample L^AT_EX code for Index usage

```
1 If we make a very large matrix with complex exponentials in the rows (i.  

   e., cosine real parts and sine imaginary parts), and increase the  

   resolution without bound, we approach the kernel of the \index{  

   Fredholm integral} Fredholm integral equation of the 2nd kind,  

   namely the \index{Fourier} Fourier operator that defines the  

   continuous Fourier transform.
```

L12 Adding Relevant PDF Pages

1518 Examples of such PDF pages are Standards, Datasheets, Specification Sheets, Application
1519 Notes, etc. Selected PDF pages can be added (see List. L.16), but note that the options
1520 must be tweaked. See the manual of `pdfpages` for other options.
1521

Listing L.16: Sample L^AT_EX code for including PDF pages

```
1 \includepdf[pages={8-10},%  
2 offset=3.5mm -10mm,%  
3 scale=0.73,%  
4 frame,%  
5 pagecommand={} ,]  
6 {./reference/Xilinx2015-UltraScale-Architecture-Overview.pdf}
```

Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Logic Cells	626,640	780,000	940,800	1,253,280	1,621,200	1,879,920	4,432,680
CLB Flip-Flops	716,160	891,424	1,075,200	1,432,320	1,852,800	2,148,480	5,065,920
CLB LUTs	358,080	445,712	537,600	716,160	926,400	1,074,240	2,532,960
Maximum Distributed RAM (Mb)	4.8	3.9	4.8	9.7	12.7	14.5	28.7
Block RAM/FIFO w/ECC (36Kb each)	1,260	1,421	1,728	2,520	3,276	3,780	2,520
Total Block RAM (Mb)	44.3	50.0	60.8	88.6	115.2	132.9	88.6
CMT (1 MMCM, 2 PLLs)	10	16	16	20	30	30	30
I/O DLLs	40	64	64	80	120	120	120
Fractional PLLs	5	8	8	10	15	15	0
Maximum HP I/Os ⁽¹⁾	468	780	780	780	650	650	1,404
Maximum HR I/Os ⁽²⁾	52	52	52	104	52	52	52
DSP Slices	600	672	768	1,200	1,560	1,800	2,880
System Monitor	1	1	1	2	3	3	3
PCIe Gen3 x8	2	4	4	4	5	6	6
150G Interlaken	3	6	6	6	8	9	0
100G Ethernet	3	4	4	6	9	9	3
GTH 16.3Gb/s Transceivers	20	32	32	40	52	60	48
GTy 30.5Gb/s Transceivers	20	32	32	40	52	60	0

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.
2. HR = High-range I/O with support for I/O voltage from 1.2V to 3.3V.



Virtex UltraScale Device-Package Combinations and Maximum I/Os

Table 7: Virtex UltraScale Device-Package Combinations and Maximum I/Os

Package ⁽¹⁾⁽²⁾⁽³⁾	Package Dimensions (mm)	VU065	VU080	VU095	VU125	VU160	VU190	VU440
		HR, HP GTH, GTY						
FFVC1517	40x40	52, 468 20, 20	52, 468 20, 20	52, 468 20, 20				
FFVD1517	40x40		52, 286 32, 32	52, 286 32, 32				
FLVD1517	40x40				52, 286 40, 32			
FFVB1760	42.5x42.5		52, 650 32, 16	52, 650 32, 16				
FLVB1760	42.5x42.5				52, 650 36, 16			
FFVA2104	47.5x47.5		52, 780 28, 24	52, 780 28, 24				
FLVA2104	47.5x47.5				52, 780 28, 24			
FFVB2104	47.5x47.5		52, 650 32, 32	52, 650 32, 32				
FLVB2104	47.5x47.5				52, 650 40, 36			
FLGB2104	47.5x47.5					52, 650 40, 36	52, 650 40, 36	
FFVC2104	47.5x47.5			52, 364 32, 32				
FLVC2104	47.5x47.5				52, 364 40, 40			
FLGC2104	47.5x47.5					52, 364 52, 52	52, 364 52, 52	
FLGB2377	50x50							52, 1248 36, 0
FLGA2577	52.5x52.5						0, 448 60, 60	
FLGA2892	55x55							52, 1404 48, 0

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale architecture-based devices with the same sequence. The footprint compatible devices within this family are outlined. See the [UltraScale Architecture Product Selection Guide](#) for details on inter-family migration.



Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
Logic Cells	689,640	1,051,010	1,379,280	2,068,920	2,147,040	2,862,720
CLB Flip-Flops	788,160	1,201,154	1,576,320	2,364,480	2,453,760	3,271,680
CLB LUTs	394,080	600,577	788,160	1,182,240	1,226,880	1,635,840
Max. Distributed RAM (Mb)	12.0	18.3	24.1	36.1	34.8	46.4
Block RAM/FIFO w/ECC (36Kb each)	720	1,024	1,440	2,160	2,016	2,688
Block RAM (Mb)	25.3	36.0	50.6	75.9	70.9	94.5
UltraRAM Blocks	320	470	640	960	1,152	1,536
UltraRAM (Mb)	90.0	132.2	180.0	270.0	324.0	432.0
CIMTs (1 MMCM and 2 PLLs)	10	20	20	30	12	16
Max. HP I/O ⁽¹⁾	520	832	832	832	624	832
DSP Slices	2,280	3,474	4,560	6,840	8,928	11,904
System Monitor	1	2	2	3	3	4
GTY Transceivers 32.75Gb/s	40	80	80	120	96	128
PCIe Gen3 x16 and Gen4 x8	2	4	4	6	3	4
150G Interlaken	3	4	6	9	9	12
100G Ethernet w/RS-FEC	3	4	6	9	6	8

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.

Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Table 9: Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Package ⁽¹⁾⁽²⁾⁽³⁾	Package Dimensions (mm)	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
		HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY
FFVC1517	40x40	520, 40					
FLVF1924	45x45					624, 64	
FLVA2104	47.5x47.5		832, 52	832, 52	832, 52		
FHVA2104	52.5x52.5 ⁽⁴⁾						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 ⁽⁴⁾						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 ⁽⁴⁾						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale devices with the same sequence. The footprint compatible devices within this family are outlined.
4. These 52.5x52.5mm overhang packages have the same PCB ball footprint as the corresponding 47.5x47.5mm packages (i.e., the same last letter and number sequence) and are footprint compatible.

Chapter M

VITA

1525



1527

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1528



1529

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1531

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1532

1533

Chapter N

ARTICLE PAPER(S)

1534