Content

Preface 9

1 Introduction 23
  1.1 Research questions 27
  1.2 Scope 28
  1.3 Content 29

2 Sources of knowledge 31
  2.1 Introduction 31
  2.2 Navigational distribution of literature and knowledge 32
  2.3 Primary literature 39
    2.3.1 The introduction of the cross-staff 42
      2.3.1.1 The kamal 42
      2.3.1.2 The mariner's cross-staff 44
    2.3.2 The instrument revolution 44
    2.3.3 New backstaff instruments 48
    2.3.4 New features 56
  2.4 Contemporary imagery 59
  2.5 Secondary literature 63
    2.5.1 Secondary literature of the period 64
    2.5.2 Nineteenth-century revival 64
    2.5.3 Twentieth-century standard works 66
    2.5.4 Instrumental monographs 69
    2.5.5 Other twentieth-century publications 70
    2.5.6 Modern works from the Iberian peninsula 71
    2.5.7 Modern works on surviving instruments 71
  2.6 Works assessing the accuracy of instruments 73
    2.6.1 Contemporary assessments 73
    2.6.2 Modern accuracy assessments 74
      2.6.2.1 Desk studies 74
      2.6.2.2 Instrumental analysis 76
      2.6.2.3 Practical tests 77
2.7 Surviving instruments and archaeological artefacts 80
  2.7.1 Instruments as a source 80
  2.7.2 Survival of the fittest? 81
  2.7.3 The most commonly used instruments 84
    2.7.3.1 The influence of prices on use 85
    2.7.3.2 Most used by survival 86
    2.7.3.3 Most commonly used according to literature 92
    2.7.3.4 Most commonly used according to estate inventories 96
    2.7.3.5 Most commonly used overall 97
  2.7.4 Rare survivors 99
    2.7.4.1 The triangular quadrant 99
    2.7.4.2 The cross-bow quadrant 100
    2.7.4.3 The kamal 100
    2.7.4.4 The hoekboog 100
    2.7.4.5 The cross-staff with spoon shaped-transoms 101
  2.8 Experiments with replicas and reconstructions 102
    2.8.1 The instruments 102
    2.8.2 Field tests 105
  2.9 Summary 108

3 The advent of shadow-casting instruments 113
  3.1 Introduction 113
  3.2 Geodesy versus navigation 114
  3.3 Back to basics 117
    3.3.1 Introduction 117
    3.3.2 Instruments for celestial navigation predating the mariner’s cross-staff 118
      3.3.2.1 The mariner’s quadrant 118
      3.3.2.2 The mariner’s astrolabe 120
    3.3.3 The introduction of the mariner’s cross-staff 122
      3.3.3.1 The Baculus Jacob or Jacob’s staff 124
      3.3.3.2 The kamal 129
      3.3.3.3 The mariner’s cross-staff 139
      3.3.3.4 Spoon-shaped transoms on the mariner’s cross-staff 144
    3.3.4 Instruments for celestial navigation at the end of the sixteenth century 151
      3.3.4.1 The mariner’s quadrant 152
      3.3.4.2 The mariner’s astrolabe 153
      3.3.4.3 The sea ring 154
      3.3.4.4 The mariner’s cross-staff 156
      3.3.4.5 The mariner’s cross-staff with vanes 158
3.4 Instruments that define the change  161
   3.4.1 Introduction  161
   3.4.2 The instruments  164
      3.4.2.1 Master Hood’s Cross-staff  164
      3.4.2.2 Harriot’s back-staffs  176
      3.4.2.3 John Davis’ back-staffs  182
3.5 Summary  192

4 New Instruments following the change  195
   4.1 Introduction  195
   4.2 The seventeenth-century mariner’s cross-staff  196
   4.3 The newly invented instruments  206
      4.3.1 The knipboogh and cromme boogh (f.l. 1600)  207
      4.3.2 The Davis quadrant (f.l. 1604)  209
      4.3.3 The removing quadrant (f.l. 1604)  250
      4.3.4 The cross-bow quadrant (f.l. 1604)  257
      4.3.5 The demi-cross (f.l. 1618)  279
      4.3.6 The hoekboog (f.l. 1623)  293
      4.3.7 The spiegelboog (f.l. 1660)  312
      4.3.8 The triangular quadrant (f.l. 1662)  337
      4.3.9 The plow (f.l. 1669)  352
      4.3.10 The almacanter’s staff (f.l. 1672)  365
      4.3.11 The improved Davis quadrant (f.l. 1677)  371
      4.3.12 The demi-quadrant (c.1750)  376
   4.4 The end of an era  383
      4.4.1 Introduction  383
      4.4.2 The octant  384
   4.5 Summary  391

5 The instrument as a concept  399
   5.1 Introduction  399
   5.2 Instrumental design  401
      5.2.1 The datum line  401
      5.2.2 Construction methods  404
         5.2.2.1 Monoxylous frames  404
         5.2.2.2 Polyxylous frames  407
         5.2.2.3 Transoms and vanes  408
         5.2.2.4 Scales  410
      5.2.3 Dividing methods  314
   5.3 In the shadow of Hood and Harriot  437
      5.3.1 Hood’s shadow-casting method  437
      5.3.2 Harriot’s shadow-casting method  438
      5.3.3 Hood vs Harriot  439
5.4 Observational reference  451
  5.4.1 Instruments relying on gravity  451
    5.4.1.1 The mariner’s astrolabe versus the mariner’s quadrant  451
    5.4.1.2 Other suspended instruments  454
  5.4.2 Instruments relying on a visible horizon  455
    5.4.2.1 The forward method  455
    5.4.2.2 The sideways method  456
    5.4.2.3 The backward method  458
  5.4.3 Instruments combining gravity and a visible horizon  479
5.5 Concept based diffusion  481
5.6 Biased observations  488
  5.6.1 The mounting-hole of transoms and vanes  488
  5.6.2 The hole in the mariner’s astrolabe  490
  5.6.3 The pinnules of the mariner’s astrolabe  491
  5.6.4 The procedure for the mariner’s astrolabe  493
  5.6.5 The eye-end error of the mariner’s cross-staff  494
  5.6.6 The mirror of the spiegelboog  501
  5.6.7 The transom length  504
  5.6.8 The shadow vane position  506
  5.6.9 Deformation of the instrument  507
5.7 Mathematics of noon  509
5.8 Instrumental rhetoric  512
5.9 Summary  518

6 Scale analysis  523
  6.1 Introduction  523
  6.2 Resolution versus accuracy  523
  6.3 Relative versus absolute scale errors  526
  6.4 Research methods  530
    6.4.1 Photo-analysis  530
    6.4.2 Photogrammetry  533
  6.5 The analysed instruments  536
    6.5.1 The geometrical cross-staff  536
    6.5.2 The mariner’s cross-staff  540
    6.5.3 The cross-bow quadrant  550
    6.5.4 The Davis quadrant  552
    6.5.5 The hoekboog  565
    6.5.6 The plow  567
    6.5.7 The demi-quadrant  569
  6.6 Summary  571
7 Replicas and reconstructions  573
  7.1 Introduction  573
  7.2 What is the use of replicas and reconstructions?  574
  7.3 Studies assessing the accuracy of early modern instruments  579
    7.3.1 Contemporary studies  582
      7.3.1.1 The 1538 journal of D. João de Castro  583
      7.3.1.2 Joost van Breen’s 1661 spiegelboog trials  586
    7.3.2 Modern studies  588
  7.4 Handling characteristics  607
  7.5 The ideal instrument  609
  7.6 Summary  612

8 Conclusion  615
  8.1 Introduction  615
  8.2 Research questions  616
    8.2.1 Which instruments were created in the research period?  616
    8.2.2 Which instrument(s) became most widely used?  617
    8.2.3 Which factors dictate the accuracy of observations taken with them?  618
    8.2.4 Did design features diffuse?  623
    8.2.5 How do replicas and reconstructions add to our understanding of the instruments?  624
    8.2.6 Answering the main research question  624
  8.3 Other findings  626
  8.4 Epilogue  627

9 Summary  631

Bibliography  635
  A. Primary sources  635
  B. Secondary sources  653
Appendices

Appendix A
Introduction to the instruments 669

Appendix B
Observational corrections 693

Appendix C
Davis quadrants around the world 703

Appendix D
‘The Doctrine of Nauticall Triangles Compendious’ 719

Appendix E
Harriot’s manuscript BL, Add MS 6788 722

Appendix F
The Jewell of Artes 730

Appendix G
Instruments made by N. de Hilster 743

Appendix H
Data 766

Indexes
Index of instruments 801
Index of personal names 807
Index of regions and places 810
General index 813