The dissemination of Jesuit military mathematics from the Collegio Romano to the Emilia-Romagna region of Italy, 1600-1750*

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One remarkable characteristic of the Society of Jesus in the Baroque age was the involvement of many of its learned members in the dissemination of mathematical knowledge. This was inspired by St Ignatius of Loyola's belief that any acquisition of knowledge was a spiritually profitable exercise. In the context of the scientific revolution that was shaking sixteenth-century Europe, it was understandable that many Jesuit mathematicians would emerge in the forefront of a massive promotion exercise involving mathematical education in its wider and more practical sense of the word which contrasted sharply with the narrow interpretation of the subject today. This was a 'mathematical disciplines' approach which went far beyond the time-honoured study of Euclid; it incorporated a wide range of topics which included Euclidean and analytic geometry, geometry as applied to calculus, to astronomy and to mechanics, the art of measuring, the sphere, trigonometry, logarithms, navigation, gnomonics and horology, the calendar, civil and military architecture. At the dawn of the Baroque age, the promotion of such a wide spectrum of mathematical knowledge invested the Jesuit *mathematicus* with great credibility which, in perfect accord

* This contribution is based on the author's wider study on the subject: Denis De Lucca, *Jesuits and Fortifications: The Contribution of the Jesuits to Military Architecture in the Baroque Age* (Leiden and Boston: Brill Academic Publishers, 2012).

with Ignatius' strategy, was considered essential to elevate the status of his invention over that of the traditional Orders. As George Sarton wrote, 'One cannot really talk about mathematics in the sixteenth and seventeenth centuries without seeing a Jesuit at every corner'.[1]

At the same time, however, the involvement of the Jesuit Order with the mathematical disciplines which were then closely associated in the minds of many with the dangerous worlds of alchemy and astrology, created problems for the new religious Order that had been canonically appointed by Pope Paul III Farnese in 1540. So did the view of many contemporary philosophers and theologians that mathematics was a subject that attracted ridicule by both professors and students of the traditional universities because it did not demonstrate its conclusions through causes but dealt instead with 'odious abstractions'. These allegations had led to a barrage of criticism directed towards the first professor of mathematics at the Jesuit College in Rome, the Spaniard Balthasar de Torres (1518-1561).[2]

The person who was responsible for placing Jesuit mathematical education on a firm footing was a German Jesuit from Bamberg called Christoph Clavius (1538-1612). Clavius served as professor of mathematics at the *Collegio Romano* during the period 1565-1612.[3] He managed to establish the Jesuit college in Rome as the most important Counter-Reformation centre of excellence and authority on the mathematical disciplines, responsible for providing undergraduate

1 George Sarton, *An appeal for the republiction in book form of Father Bosman's studies on Belgian mathematics in the sixteenth and seventeenth centuries.* In ISIS 40, cited by Angelo De Bruycher in *A matter of opportunities? Jesuits practising mathematics in the seventeenth century Spanish Netherlands*, paper presented at the 17th Novembertagung on History and Philosophy of the Mathematical Science Studies Unit of the University of Edinburgh, 3-5 November 2006.

2 A[rchivum] R[omanum] S[ocietatis] I[esu], A(rchivum) H(istoricum) S(ocietatis) I(esu) 103, a. LII (1983), 56-92 (article on '*Jesuiten-Mathematiker in Frankreich und Italien*' by K.A.F.Fischer). See also Gorman, Michael John., *The Scientific Counter-Revolution: Mathematics, natural philosophy and experimentation in Jesuit culture, 1580 - c.1670*, Ph.D. thesis (European University Institute, Florence, 1998), 61-64.

3 ARSI, AHSI 103, a.LII (1983), 84 and 87. See also Ugo Baldini, ed., *Saggi sulla cultura della Compagnia di Gesù, secoli XVI-XVIII* (Padova: CLEUP Editrice, 2000), 17 who mentions E. Knobloch 's contribution on Clavius entitled *Sur la vie et l'oeuvre de Christophore Clavius* in '*Revue d'histoire des sciences*' 42 (1988).

training to all Jesuit students in the second year of their two-year philosophy course and postgraduate training of a minimum one year duration, given to gifted Jesuit scholastics (within an '*Accademia di Matematica*') who would then be sent to teach the mathematical disciplines in the different provinces of the Order.[4] Apart from inspiring the rapid dissemination of Jesuit mathematical knowledge in several European colleges and special Jesuit schools known as 'seminaries for nobles', Clavius also encouraged the type of private tuition arrangements that were often made by the Jesuits for mature 'external students' in positions of power and influence.

Clavius relied on a very efficient Jesuit print culture to rally support for his stand. One case in point was his publication of a document entitled *Modem quo disciplinae mathematicae in Scholis Societates possent promoveri* (1582) where the following paragraph particularly emphasised the importance of mathematical knowledge in Jesuit campaigns for religious dominance:

> Mathematics will also bring great ornament to the Society where noblemen would understand that our Jesuits are not ignorant of mathematics, for this subject is discussed very frequently in their conversations and meetings. For this reason, our Jesuits, would incur great shame and disgrace if they were to remain silent in gatherings of this kind, as has been related most frequently by those who were thus embarrassed.[5]

While such comments clearly imply that one reason for the Jesuit interest in the mathematical disciplines was to accommodate the requirements of the ruling nobility of the Baroque age, another reason would have been the more than welcome reconciliation of the post-Tridentine Catholic Church with mathematical teaching. This had happened when Clavius – who had been heavily involved in formulating

4 Jesuit academies consisted in either one or a combination of five options: a seminar or extended debate on a previously identified topic, a course of lessons focused on a particular subject, an extra-mural course for adults, a special class focused on matters which dealt with marginally in ordinary Jesuit colleges or a '*corso di perfezionamento*' offering postgraduate education. See Baldini, *Saggi*, 49-98.

5 ARSI, *Monumenta Paedagogica Societatis Iesu*, VII, 115-117 .

the new Gregorian Calendar that was promulgated by Pope Gregory XIII Boncompagni's Bull *Inter gravissimos* of 24 February 1582 – used the Jesuit press to defend his role as papal mathematician from a ferocious attack on the new papal calendar encapsulated in a lengthy document prepared in 1583 by Kepler's teacher Michael Maestlin.[6] On this occasion, Clavius had enlisted the help of a Jesuit scholar from Mantova called Antonio Possevino (1534-1611) who was much more accustomed to battling with these troublesome 'heretics' than he was. Possevino, in characteristic style, did not hesitate to use the words 'incompetence' (*imperitiam*) and 'vanity' (*vanitatem*) to describe Maestlin's document.[7] Another early confrontation which Clavius had to face was with that prominent Jesuit professor of philosophy Benito Pereira (1535-1610) who in his 1591 book entitled *Adversus Fallaces et Superstitiosas Artes* (1591) highlighted the dangers of teaching mathematics because of 'its very questionable relationship' with practical astrology. Among other things, Pereira argued that the Spanish Inquisition run by the rival Dominican Order would be presented a golden opportunity to pounce upon any perceived malpractices in the handling of this subject by Jesuit professors.[8] Upset by such criticism but encouraged by the pope's declaration that the teaching of mathematics was legitimate since it could be seen to be of clear benefit to contemporary society, Clavius insisted that a competent Jesuit *mathematicus* was more capable of providing true knowledge than the philosophy professors who were more often than not

6 Gorman, *Scientific Counter-Revolution*, 25, text and fn. 26.

7 Antonio Possevino S.J., *Moscovia, et alia opera, de statu huius seculi, adversus Catholicae Ecclesiae hostes* (Vilnius: apud Ioannem Velicensem, 1586). For Possevino's battles against 'heretics' in the Valtelline, see Theodor Griesinger, *The Jesuits: A Complete History of their Open and Secret Proceedings from the Foundation of the Order to the Present time* (London: W.H. Allen & Co., 1903), 166 who alleges that Possevino at the head of 2000 soldiers once attacked the village of St. Germain, killing all the male inhabitants and burning two reformed clergymen 'on a slow fire'.

8 Benito Pereira S.J., *Adversus Fallaces et superstitiosas artis, id est, de magia, de observatione somniorum, et de divinatione astrologica*, Libri tres (Ingolstadt, 1591 and Venice: apud Ioannes Baptista Clottum, 1592). For details of the Papal Bull *Coeli et Terrae* see by Germana Ernst, 'Astrology, Religion and Politics in Counter-Reformation Rome', in Stephen Pumfrey, Paolo Rossi, and Maurice Slawinski, eds., *Science, Culture and Popular Belief in Renaissance Europe* (Manchester: Manchester University Press, 1991), 249-273.

embroiled in controversies, such as those on which form of Aristotleianism truly represented the thoughts of the Master.[9] Besides, there was the advantageous use of mathematical knowledge in the military operations of Catholic armies, of the *genre* that Clavius had earlier described in his *Sphaeram Ioannis de Sacro Bosco Commentarius* (1570):

> We should not overlook what happened not many years ago when the leader of the army of the King of Spain snatched away the whole army of Christians from imminent death with the help of this Divine Discipline, on the island of Jamaica. When the entire Spanish army was in the most extreme danger of death, and the General could not find any way to provide food from the Jamaicans, he ordered that it should be announced to the leaders of the Jamaicans that unless they provided all the necessary food to himself and his army, they would suffer many terrible evils. They would see the moon to be darkened not long afterwards to bear witness to this fact. As he was excellently versed in astronomy, he knew that the moon was about to be eclipsed. At first the Barbarians made light of the commands and threats of the Christian General, but when they perceived the moon to be eclipsed at the time at which he had stated, and did not understand the cause of this matter, they gave complete faith to the words he had uttered before, provided the Christians with abundant provisions and rushed to fall at the feet of the same General and the rest of the army, so that they forgot themselves and were left in a terrible state of need.[10]

Beyond this very first Jesuit reference to possible mathematical applications in military operations, two important aspects of early Jesuit interest in military affairs were Clavius' interest in Possevino's call for world evangelisation and his role in the drafting of the 1599 *Ratio Studiorum* which, among other things, established on a firm

9 Christoph Clavius, S.J., *Euclides elementorum libri XV, Accesit XVI de solidorum regularium comparatione* (Rome: Vincentium Accoltum, 1574), *Prolegomena.*

10 Clavius S.J., Christoph, *In Sphaeram Ioannis de Sacro Bosco commentarius* (Rome: Victorium Helianum,1570), 11-12.

basis the status of the professors of the mathematical disciplines in the higher faculties of the Jesuit college. With regards to the first aspect, Possevino, in Book XV of his celebrated encyclopedia of Catholic knowledge entitled *Biblioteca Selecta* (1593) had acknowledged that 'in this matter, among others, the judgement and the excellence of Christoph Clavius, the *mathematicus* of our Society, were of enormous help to me'.[11] Referring to the association of mathematics with the art of war, a very significant entry in Possevino's *Biblioteca Selecta* entitled '*Ars Militaris inter Mathematicas Numeranda*' criticised those who:

> had rejected the military arts which some had already called Mathematics and which really appertains to the formation and co-ordination of lines of battle, on the grounds that this was only computation, similar to what happens in the reviewing of troops, in the measurement of land and in the partitioning of spaces in the military camp.[12]

Such comments suggest that the time was ripe for the Jesuits to openly appreciate the possible military applications of the subject in the context of Biagioli's witty observation that, after the sweeping invasion of Italy by King Charles VIII of France in 1494-1495 in an attempt to seize the Neapolitan throne, 'the cannon-syndrome and the introduction of the bastion forced the *milites*, the professional warriors of aristocratic origins, to begin to rely less on their horses and more on Euclid for their survival as a distinct social group'.[13] By 1600 the great military leaders of Catholic Europe had indeed become greatly interested in Jesuit mathematical teaching, grasping every opportunity to show their support for the Society of Jesus as a sign of gratitude for the advice on military matters that they regularly received from Jesuit mathematicians.

Clavius' role in the drafting of the 1599 *Ratio Studiorum* was also

11 Possevino S.J. Antonio, *Biblioteca Selecta qua agitur de Ratione Studiorum, in Historia, in Disciplinis, in Salute omnium procuranda* (Rome, 1593).

12 *Ibid.*, book XV, chapter II, para. [E].

13 Mario Biagioli, The Social Status of Italian Mathematicians. In 'History of Science', 27 (1989), 1-75.

significant. His involvement here can be traced back to the very first drafts of the document compiled during the period 1565-1572 by the Jesuits Nadal, Borgia and Ledesma which was followed by at least two other preliminary drafts in 1586, two others in 1591 and 1592 and the final version in 1599.[14] Resisting pressures to the contrary from the high and the mighty, Clavius tactfully managed to avoid including explicit military applications in his '*Modus quo disciplinae mathematicae in Scholis Societatis possint promoveri*' (1582) and other documents, although one can notice that '*Opera Archimedes*' was listed as one of the many subjects included under '*disciplinis mathematicis*' in an earlier document authored by Clavius in 1581.[15] The learned Jesuit professor seems to have been very conversant with the military contribution of the ancient Greek mathematician since in his '*Euclides Elementorum Libris XV*' (1574), Clavius wrote:

> When Hieron, King of the Siracusans, built a warship that he intended to send to Ptolemy, King of the Egyptians, it was so heavy that all the Syracusans working together were unable to move it. Archimedes, most skilled in geometry, promised the King that he would ensure, by the power of geometry alone, that the King himself could move the ship by only the powers of geometry. When he carried this out, in view of everyone, the King is said to have exclaimed with astonishment, 'from this day on, whatever Archimedes says, he is to be believed'.[16]

As a result of his good work, Clavius single-handedly managed to give a new image to the teaching of the mathematical disciplines at the Roman college where the students 'would be greatly drawn to these studies if once a month all the philosophers would gather in a single place and one of the students explained some astronomical or geometric problem, which would both be fun for the audience and useful for the

14 George E. Ganss S.J., *The Constitutions of the Society of Jesus* (St. Louis: Institute of Jesuit Sources, 1970).

15 ARSI., *Mon.Paed.*, VII, 110-113 (I4-I) [*Ordo serrandus in addiscendis disciplinis mathematicis*]

16 Clavius, *Euclides elementorum*, f.6v.

humanities'.[17] The assistants and successors of Clavius all contributed to the dissemination of mathematical knowledge from the Roman college to seventeen chairs of mathematics in Italy,[18] seven in Spain,[19] four in Portugal, thirty in France[20] and forty-three in Germany.[21] Such was the reputation of Jesuit mathematical investigation that in 1603, Clavius' future successor Christoph Greinberger was able to confidently introduce his '*Problemata*' as follows:

> the boldness of mathematicians has always been great, as has their power, most religious fathers and honourable members of the audience; they possess so much spirit in a small number of people, that there is nothing in the whole universe either cloaked in darkness or buried in difficulties, that has been able to escape their ingenuity and that has not been investigated with their machines.[22]

Further on in this address delivered to the applause of the many Jesuits, church dignitaries and nobles gathered in the grand hall of the Roman college for the occasion, Grienberger praised Archimedes' military exploits at the siege of Syracuse in 213 BC. His contribution paved the way for the Jesuit application of mathematics to the military domain in a scenario that had, since 1580, been characterised by innumerable armed conflicts of a religious nature – wars where the Roman papacy was perceived by many Catholics as struggling for survival against the ferocious onslaughts of Protestant

17 ARSI., *Mon. Paed.*, VII, 117 (14-II) [*Modus quo disciplinae mathematicae in Scholis Societatis possent promovere*]

18 Charles E. O'Neill S.J., and Joaquin M. Dominguez S.J., ed., *Diccionario Historico de la Compañia de Jesús Biografico–Tematico* (Rome: Institutum Historicum Societatis Iesu and Madrid: Universdidad Pontificia Comillas, 2001) 2571-2574 (*Matemáticas*). See also ARSI, AHSI 103, a.LII(1983) 79-92.

19 O'Neill and Dominguez, *Diccionario*, 2572 (*Matemáticas*).

20 *Ibid.* See also ARSI, AHSI 103, a.LII (1983), 56-78.

21 *Ibid.* See also K.A.F. Fischer, *Jesuiten-Mathematiker in der Deutschen Assistenz.* In 'AHSI' 93, a.XLVII (1978), 159-224.

22 Michael John Gorman, *Mathematics and Modesty in the Society of Jesus: the problems of Christoph Grienberger.* In Mordechai Feingold ed., *The New Science and Jesuit Science: Seventeenth-Century perspectives* (Dordrecht, 2003), fn.77.

'heretics' and Turkish 'Infidels'. In this respect, one of the most prominent contemporary Jesuit writers on Catholic war ethics targeted at these 'devilish forces' was the above-mentioned Antonio Possevino who was writing in a century when Erasmus of Rotterdam (1466-1536), Nicolò Machiavelli (1469-1527), Thomas More (1478-1535), Martin Luther (1483-1546), Jean Calvin (1509-1564), Francisco de Vitoria (1492-1546) and Hugo Grotius (1583-1645) had all expressed their opinions about the concept of a 'just war' in its wider Christian context. Possevino first in the Waldensian valleys and later in France wrote two outstanding works entitled *Il Soldato Christiano* (1569) and the *Iudicium De Nuae Galli scriptis* (1592). The first book was commissioned by Pope Pius V Ghislieri (1566-1572) for distribution among the soldiers of the Catholic army that he had sent to King Charles IX of France (1560-1574) to help him suppress the Huguenot rebels and also among the troops that were then being mobilised by Don Juan of Austria to keep the Turks at bay. The second work was essentially an aggressive response to the publication of a Protestant best-seller authored by the Huguenot general François de la Noue (1531-1591). This controversial work which called for the formation of a united force composed of Catholics and Protestants to attack Constantinople was entitled *Discours Politique et Militaires* (1587).[23]

The spark that was lit by Possevino's writings was perpetuated in the works of other distinguished Jesuits, most of whom were directly associated with the religious wars that were being waged by the kings of France and Spain, eventually leading to the 1618-1648 Thirty Years War. Émond Auger[24] authored a book about military instruction entitled *Le Pedagogue d'armes pour instruire un Prince Chrestien* (1568). Thomas Sailly[25] wrote the important work *Guïdon et Pratique Spirituelle du Soldat Chrestien* (1590) for distribution among the Catholic forces in

23 For biographical information about Noue see Amirault, *La vie de Francois, seigneur de la Noue* (Leiden: Jean Elsevier, 1661) and Henri Hauser, *Francois de la Noue* (Paris: Hachette, 1892). An English translation of Noue's book by Orwin was published in 1587.

24 O'Neill and Dominguez ed., *Diccionario* 268-270 (*Auger*).

25 ARSI, S[om]M[er]V[ogel] S.J., Carlos., *Bibliothèque de la Compagnie de Jesús* (SMV), Volumes I-X (Brussels, Paris and Tolouse, 1890-1932), 403-406 gives a concise biography of Sailly.

the Netherlands led by general Alessandro Farnese to whom Sailly's work was dedicated. Francisco Antonio was the author of *Avisos Para Soldados* (1590)[26] and 'just war' expositions were also forthcoming from the distinguished Jesuit philosophers Luis de Molina[27] and Francisco Suarez[28] who both emphasised the need of the Jesuit Order to support wholeheartedly the wars that were being waged on many fronts against the dark forces of Protestantism and Islam. In 1604, the Jesuit Pedro Ribadeneira published his *Princeps Christianus*, further fuelling Jesuit militancy against the 'plague' and 'venom' of heresy.

At this time many were the non-Jesuit mathematicians who also started becoming interested in the military applications of their subject. One notes the contents of the 1614 programme of Johann Valentin Andreae (1586-1642),[29] the 1617 programme of Robert Fludd (1574-1637),[30] the 1644 programme of Pierre Herigone (1580-1643)[31] and

26 ARSI, SMV, I, 442. See also O'Neill and Dominguez ed., *Diccionario*, 1246-1248 (*Enseñanza Militar*).

27 For Molina's *De Iustitia et Iure* (1614) see Gregory M., Reichberg, Syse, Henrik and Begby, Endre., *The Ethics of War* (Malden, Mass. and Oxford: Blackwell, 2006) 333-338. Molina (1530-1600) justified military offensives to avenge inflicted injury and to recover property intensifying a generally intolerant Jesuit attitude towards 'heretics' and 'infidels'.

28 For Suárez's *De Bello* (1621), see Reichberg *et.al.*, *Ethics of War*, 339-370. Suárez (1548-1617) advocated the principle that the 'punishment' of war had to be inflicted with utmost restraint and caution, in view of its detrimental effects on mankind.

29 Andreae, Ioannis Valentini, *Collectaneorum mathematicorum decades XI; Centum et decem tabulis Aeneis exhibitae* (Tubingen: typis Iohan Alexandri Cellii, 1614) incorporating geometry, arithmetic, statics, astronomy, gnomonics, automata, optics, architecture, fortifications, surveying and polyhedra. The Lutheran Andreae was also the author of *Reipublicae Christianopolitanea* (1619) which discusses an ideal state of the seventeenth century, focusing on 'principles of fortifications' and 'moral defences', influenced by Tommaso Campanella's *Città del Sole* (1602).

30 Robert Fludd, *Utriusque cosmi maioris scilicet et minoris metaphysica physica atque technica* (Oppenheim: typis Hieronymi Galleri, 1617) incorporating arithmetic, music, geometry, optics, pictorial art, military art, the science of motion, the science of time, cosmography, astrology and geomancy.

31 Pierre Herigone, *Cursus Mathematicus, brevi et clara methodo demonstratus: Tome III continens constructionum tabularium sinum et logarithmorum eum earum usu in anatoxism et triangulorum rectilineorum dimensione geometricam practicam, artem muniendi, militam et mechanicas* (Paris: Simeon Piget, 1644) incorporating Euclid and theoretical geometry in its first section; arithmetic, computation, algebra and analysis in its second section; trigonometry, practical geometry, fortifications,

the 1730-1738 programme of Christian von Wolff (1679-1754).[32] Their achievement can be compared with the 1641 curriculum devised by the distinguished Jesuit *mathematicus* Jan Ciermans (1602-1648)[33] who with remarkable inventiveness chose to teach his students a dozen mathematical disciplines corresponding with the twelve months of the year: geometry, arithmetic, optics, statics, hydrostatics, nautical science, military architecture, logic, war machines, geography, astronomy and chronology. There was then the 1674 curriculum devised by the renowned Jesuit mathematician Claude François Milliet

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military arts and mechanical applications in its third section; the study of the sphere, geography and navigation in its fourth section and the study of optics, caloptrics, dioptics, perspective, spherical trigonometry, planetary theories, gnomonics and music in its fifth section. Herigone's '*artem muniendi*' discussion consists of two parts, the first with twelve chapters concerning 'regular fortifications' and the second answering 9 problems posed by 'irregular fortifications'. The real name of Herigone was Clement Cyriaque, Baron de Mangin.

32 Christian von Wolff, *Elementa matheseos universae: Tome IV: Geographiam cum hydrographia, chronologiciam, gnomonicam, pyrotechniam, architecturam militarum atque civilem* (Halle: In Officina Libraria Rengeriana, 1730-1738) incorporating mathematical method, arithmetic, geometry and trigonometry in its first section; mechanics with statics, hydrostatics, aerometry and hydraulics in its second section; optics, perspective, caloptrics, dioptics, the sphere, spherical trigonometry and astronomy, spherical and theoretical, in its third section and geography with hydrography, chronology, gnomonics, pyrotechnics and civil and military architecture in its fourth section.

33 Ciermans S.J., J., *Annus Positionum Mathematicorum quas defendit ac demonstravit perill. Dom D. Wolffgangus Philippis Iacobus Unverzagt, Baro de Ebenfurt: Mense October Geometricae, Mense Novembri Arithmeticae, Decembri Opticae, Ianuvario Staticae, Februario Hydrostaticae, Martio Nautical, Aprili Architectonicae, Maio Polemicae, Iunio De Machinis bellicis, Iulio Geographicae, Augusto Astronomicae, Septembri Chronologicae* (Louvain: Everardum de Witte, 1640-1641). According to MacDonnell S.J., Joseph., *Jesuit Geometers: a study of fifty-six prominent Jesuit geometers during the centuries of Jesuit History* (St. Louis: Institute of Jesuit Sources, 1989) 11 this Jesuit *mathematicus* used the lunar year of 354 days as the basis of his work, dividing the month into 3 parts, as did previous Muslim authors from whom he may have got the idea. According to Cobos-Guerra, Fernando and Fernandez, José Javier de Castro., *Los Ingenieros, Las Experiencias y Los Escenarios de la Arquitectura militar española en el siglo XVII* in '*Los Ingenieros militares de la monarquia hispañica en los siglos XVII y XVIII*' (Spanish Ministry of Defence *et al.*, undated) the 1640-1641 course of Ciermans was tailor-made to teach Spanish military officers in the occupied Netherlands.

de Chales (1621-1678)[34] who drew up a very influential programme of instruction based upon the books of Euclid, Arithmetic, the sphaerics of Theodosius, trigonometry, practical geometry, mechanics, statics, geography, magnetism, civil architecture, the art of carpentry, the art of the stone cutting, military architecture, hydrostatics, fountain and river studies, hydraulic machines, navigation, optics, perspective, caloptrics, dioptics, music, pyrotechnics, astrolabes, gnomonics, astronomy, calenders, astrology, algebra, meteors and conics.

When one considers that Clavius had included no less than twenty-two mathematical disciplines in his *Ordo servandus in addiscendis disciplinis mathematicis* of 1581 – including Euclid, arithmetic, the sphaerics according to Theodosius, instrumentation (quadrants and astrolobes), algebra, horology, geography according to Gemma Frisius, Archimedes, perspective, astronomy, music and mechanics – one marvels at this wide spectrum of mathematical knowledge in the Baroque age. An application of great interest was undoubtedly that concerning the measurement of time which had great military relevance in the war theatres of seventeenth and eighteenth-century Europe. Realising that a fortress could only hold out in siege conditions until a stormable breach had been made in its main line of defence, the objective of any military engineer attacking the place would have been to speed up this process while that of the defender would have been to

34 Claude Francois Milliet de Chales S.J., *Cursus seu Mundus Mathematicus: I, Tractatus I: Euclidis Elementorum; Tractatus II: Arithmetica; Tractatus III: Theodosii Elementa Sphaerica; Tractatus IV: Trigonometria; Tractatus V: Geometria Practica; Tractatus VI: Mechanice; Tractatus VII: Statica seu de gravitate Terrae; Tractatus VII (untitled); Tractaus VIII: Geographia; Tractatus IX: De Mognete; Tractatus X: Architectonica Civilis; Tractatus XI: Ars Tignaria; II Tractatus XII: De Lapidum Sectione; Tractatus XIII: Architectura Militaris; Tractatus XIV: Hydrostatica; Tractatus XV: De Fontibus Naturalibus & Fluminibus; Tractatus XVI: De Machinis hydraulicis; Tractatus XVII: Navigatio; Tractatus XVIII: Optica; Tractatus XIX: Perspectiva seu de radio directo; Tractatus XX: Caloptrica seu de radio reflexo; Tractatus XXI: Dioptrica seu de radio refracto; III Tractatus XXII: Musica; Tractatus XXIII: Pyrotechnica; Tractatus XXIV: De Astrolabiis; Tractatus XXV: Gnomonica seu de Horologiis; Tractatus XXVI: Astronomia; Tractatus XXVII: Kalendarium; Tractatus XXVIII: Astrologia; Tractatus XXIX: Algebra; Tractatus XXX: De Indivisibilibus and Tractatus XXXI: De Sectionibus Conicis* (Lyon: Officina Anissoniana, 1674), dedicated to Duke Carlo Emanuele II of Savoy.

delay this event for as long as possible by the construction of sprawling outworks in and beyond the ditch. The further these outworks stretched in front of the principal line of defence, the further away had the enemy to commence his siege operations – which included the excavation of mining tunnels, the formation of approach trenches and the mounting of gun batteries – before coming to grips with the main line of defence, all this necessitating careful timing calculations. At the same time, all fortification outworks had to be geometrically designed so as to be flanked and supported by the cannons and musket fire since any face not properly covered by flanking fire would have been identified as a weak point in the defensive network. In this context, it was of paramount importance that all the outworks had to be dominated by the artillery platforms of the works behind them so that if captured, they could first be swept by lethal back fire and afterwards, at an opportune moment, be blown up from beneath by means of a series of accurately-timed explosions of gunpowder stored in barrels concealed in invisible underground chambers called countermines. This again introduced a crucial time factor in the military operations of the defenders, not to mention all those mensuration, surveying and recording procedures that were necessary for the construction of such elaborate works. All this suggests that in a century of continuous warfare described by Fulvio Testi as 'the century of the soldier',[35] the wide spectrum of mathematical knowledge that was promoted by Clavius at the *Collegio Romano* would have had great practical value which was indeed worthy of dissemination 'for the sole defence', as one Jesuit mathematician called Giacomo Masò declared, 'of the true Catholic Faith'.[36]

The contribution of the Roman college towards the dissemination of Jesuit knowledge about mathematical applications to military architecture in the Emilia-Romagna region of Italy, the subject of this paper, constitutes an interesting subject. The material that has been published indicates that by 1600 the *Collegio Romano* had managed to achieve an international reputation for excellence in mathematical

35 Rosario Villari, ed., *Baroque Personae* (Chicago and London: University of Chicago Press, 1995), 32, Chapter 2 on *'The Soldier'* by Geoffrey Parker).

36 Giacomo Masò S.J., *Trattato dell'Architettura Militare defensiva, et offensiva* (undated manuscript: Mss E.63) 328 kept in the B[iblioteche] R[iunite] C[ivica e "A. Ursino" Recupero di] C[atania], *Civ. Mss* E. 63.

Figure 1: Christoph Clavius (1538 - 1612)

teaching and research.[37] Among the eminent Jesuit professors who taught the subject then known as '*matematica*', '*mathesis*' or '*mathematicae scientiae*', one name stands out. Oratio Grassi (1583-1654), the professor of mathematics at the Roman college in the periods 1616-1624 and 1626-1628,[38] was the architect of the magnificent churches of St. Ignatius in Rome and of the Assumption in Savona but also a respected consultant in *De re militari.* So well known was Grassi's encyclopaedic knowledge about all things military that his opinions about the new fortifications that were then being built in Malta to resist the Turks, had been the subject of long discussions held in September 1638 between the Jesuit, then residing in Savona, and the special envoy of the Grand Master of Malta, Giovanni Battista Vertova.[39] Grassi's written report, presented to the Grand Master Lascaris following Vertova's return to Malta in February 1639, reveals that prior to his meeting with Vertova the Jesuit mathematician had already carefully evaluated the military situation in Malta from plans that had been sent to him by Cardinal Francesco Barberini, the nephew of the great Pope Urban VIII Barberini (1623-1644) and Cardinal Protector of the Hospitaller Knights of St. John in Malta.[40] In his report, Grassi praised the military engineer Pietro Paolo Floriani's masterly treatment of the tenailles that he had introduced in his new line of defences, describing them as '*di forma reale e pezza di ottima difesa*' requiring 'well-trained musketeers' to defend them properly.

The powerful military mind of Grassi was reflected in the classroom lectures of two other eminent Jesuit professors who taught at the *Collegio Romano* in the seventeenth century. These were Giuseppe

37 Baldini, Saggi, 49-98. See also Ugo Baldini, *Legem impona subactis: Studi su Filosofia e scienza dei gesuiti in Italia, 1540-1632* (Rome: Bulzoni, 1992) and Dear, P., *Jesuit mathematical science and the reconsitution of experience in the early seventeenth century.* In '*Studies in history and philosophy of Science*' 18 (1987), 133-75.

38 ARSI, AHSI 103, a.LII (1983), 84 and 88. For the career of Grassi, who joined the Jesuits on 18-10-1600, see ARSI, SMV, III, 1806.

39 Denis De Lucca, *Giovanni Battista Vertova: Diplomacy, Warfare and Military Engineering Practice in early seventeenth-century Malta* (Malta: Midsea Books Ltd, 2001), 18-43.

40 *Ibid,* Grassi's report is kept in the Vatican Secret Archives *Fondo Chigi,* Q. III. 69, ff. 41v-46 where it was first identified by Roger De Giorgio, *A City by an Order* (Malta: Progress Press, 1986), 191, 259.

Ferroni (1628-1709)[41] and Francesco Eschinardi (1623-1703).[42] Ferroni, one of the more prominent post-Clavius mathematicians, taught mathematics at the Roman college during the period 1657-1660.[43] Among nine manuscripts revealing the nature of his lectures on such diverse subjects as algebra, horology, geometry, perspective and astronomy kept in the *Biblioteca Oliveriana di Pesaro*, one finds a manuscript entitled *Architectura Militaris* (1658).[44] It concerns the Jesuit's teaching of military architecture, as understood by one of his more talented students from Pesaro called Domenico degli Abbati Olivieri who was studying at the Roman college in the period 1652-1660 and who, on completion of his studies had decided to delve further into the subject of military architecture and artillery. In 1661 this Domenico attended private lessons at Bologna given by Padre Francesco Maria Minii de' Chierici minori who was the author of a manuscript entitled *Compendio di fortificazione si difensiva come offensiva.*[45] Domenico's classroom notes seem to cover only the first part of Ferroni's intensive course in military architecture which was introduced with a discussion on the usual subdivision of 'military architecture' into offensive (siege) and defensive (fortification) components and of 'fortifications' into regular and irregular types, moving on to a detailed step-by-step geometrical construction of an 'ideal citadel' of pentagonal form, explained both in plan and section.

This was not at all surprising since the building of citadels, inspired

41 ARSI, AHSI 103, a.LII (1983), 80, 82, 85 and 88. For the career of Ferroni, who joined the Jesuits on 22-10-1641 see ARSI, SMV, III, 696 and IX, 333 and Baldini, *Saggi*, 228, fn 29. (Chapter VII on *Testi e corsi secenteschi del Collegio Romano della Compagnia di Gesu in Codici dell'Oliveriana*). See also Mario Torrini, '*G. Ferroni, gesuita e galileiano*'. In '*PHYSIS*' 15 (1973).

42 ARSI, AHSI 103, a.LII (1983) 85 and 88. For the career of Eschinardi, who joined the Jesuits on 04-10-1637, see ARSI, SMV, III, 431-435 and Baldini, *Saggi,* 230, fn37.

43 B(iblioteca) O(lveriana di) P(esaro), Ms. 490 (*Trattati Gesuitici*) cited in Baldini, *Saggi,* 233 who also mentions other Oliveriana manuscripts by Ferroni on algebra and astronomical observations (Ms.180), perspective (Ms. 490) and clocks (Ms. 491).

44 B(iblioteca) O(lveriana di) P(esaro), Ms. 490 (*Trattati Gesuitici*) cited in Baldini, *Saggi,* 233 who also mentions other Oliveriana manuscripts by Ferroni on algebra and astronomical observations (Ms.180), perspective (Ms. 490) and clocks (Ms. 491).

45 Baldini, *Saggi*, 215-216 and 234, fn. 49.

by the sixteenth-century models that had been designed by the military engineer Francesco Paciotto at Turin and Antwerp, was one of the major fortification activities of the seventeenth century. One example was the immensely powerful pentagonal citadel built in Ferrara in 1608-1618 as a symbol of the dominion of the papal legate over the city following the devolution of 1597.[46] In this respect, Ferroni would have defined the function of these citadels as that of not only acting as a last refuge for the citizens of the town in times of war but of primarily ensuring the safety of an unpopular prince or governor who would follow the example of the papal legate to Ferrara and take up residence with a picked garrison within the walls of the citadel as a safeguard against a popular uprising. Such secure positions would also have to adhere to certain 'maxims'. They had to be built on the strongest site of the city – ideally on rocky elevated territory to ensure a position of dominance and avoid the possibility of undermining. They would have to control the main gateway of the city. They would have to be strategically located with respect to any rivers or ports likely to be penetrated by a potential attacker. They would need to have two gateway connections – one with the city (to allow the help of the citizens in the case of an attack by a common enemy) and one with the outside (so as to enable rapid evacuation but also to admit reinforcements in the case of a popular uprising).

The lines and angles of the fortifications of the citadel would therefore have to be devised to offer maximum protection from both internal and external assault, determining thus all decisions taken with regards to the positioning of its bastions in relation to the fortifications of the city. An important provision in this respect was to remove the flanks from the city bastions closest to the citadel so as to expose them to sweeping fire from the citadel defences from where the muskets and cannons of the garrison could wreak havoc on any insurgents occupying these bastions. Ferroni would have finally advised his students to ensure a high level of accuracy in planning citadels because of the severe

46 For information about the citadel of Ferrara and other citadels see Martha Pollak, *Cities at War in Early Modern Europe* (New York: Cambridge University Press, 2010). For seventeenth-century Jesuit teachings on citadels see De Lucca, *Jesuits and Fortifications*, 294 and 300-301.

restrictions posed by the existing contents of an older urban context. This typically-Jesuit humane consideration contrasted sharply with the bulldozing attitudes of many military engineers of the Baroque age which often resulted in slum conditions – considered by many to be 'medically' and 'morally' unhealthy.

Ferroni's typical schoolmaster's discourses seem to have represented only a fragment of a wider and more intensive investigation on military architecture. This is suggested by a second manuscript in the Pesaro library – presumably also deposited there by the same Domenico degli Abbati Olivieri – authored by Francesco Eschinardi who later served as the professor of mathematics at the Roman college in 1665-1666 and 1684-1686. This 1660 manuscript entitled *Trattato di fortificare alla moderna*[47] forms but one of four precious bundles of classroom notes dealing with astronomy, metaphysics and mechanical engineering, all taught by this Jesuit. The contents, repeatedly using derivatives of the Italian word *insegnare* meaning 'to teach', explicitly reveal Eschinardi's approach to teaching military architecture to an international class of students. It is very logically organised in eight sections covering fortification jargon; basic geometry; calculations and measurements to draw up a plan of a regularly shaped fortification complete with outworks comprising ravelins, lunettes, demilunes, covered ways, counterscarps, entrenchments and glaces; cross-sectional studies; design details of bastions, curtain walls, cavaliers, parapets, gun emplacements, ditches, crown works, tenailles, casemates and double lines of fortifications; the advantages and disadvantages of irregularly shaped fortifications in plains, marshland, sea environments, river environments and mountainous terrain; mining operations and the use of various forms of artillery.

While Eschinardi seems to have spent most of his teaching time in Rome, Ferroni eventually took up teaching posts in Mantova (1660-1666), Bologna (1667-1686) and Siena (1686-1695) where he spent the last days of his life.[48] Ferroni's involvement in Bologna, where lectures

47 BOP, Ms. 490 cited in Baldini, *Saggi,* 233 who mentions other Oliveriana manuscripts by Eschinardi on geography (Ms.184), metaphysics (Ms.189) and mechanics (Ms. 493). The last manuscript also contains the Minii *Compendio* mentioned in the text (BOP, Ms 493, ff. 1-71v)

48 ARSI, AHSI 103, a.LII (1983) 80, 82, 85, 88.

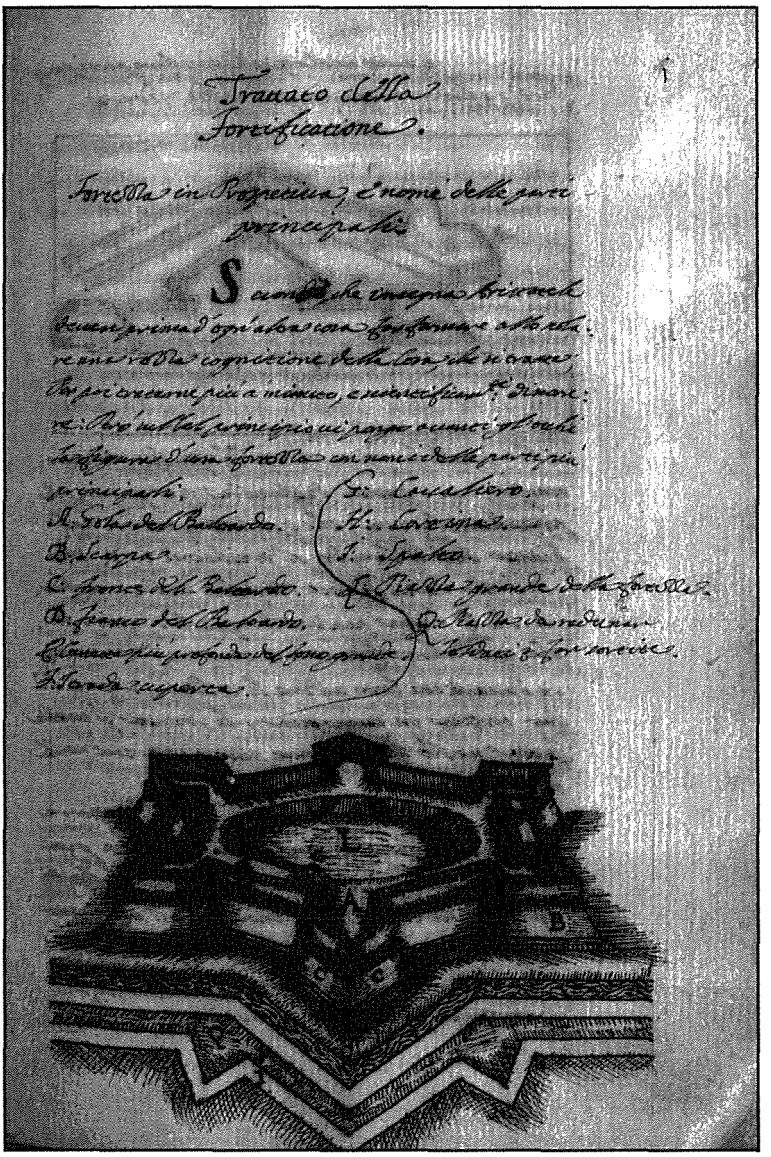

Figure 2: Francesco Eschinardi's 'Trattato di fortificare alla moderna' (1660)

in mathematics had been held since 1646 by the Jesuits Giovanni Battista Riccioli (1646-1648), Francesco Maria Grimaldi (1648-1663), Giovanni Paolo Tura (1664-1665) and Giovanni Macrini (1665-1667),[51] seems to have been particularly fruitful. Ferroni's immediate predecessor here, Giovanni Macrini (1632-1698) had himself been very interested in mathematical applications to fortifications. He had produced a treatise about the subject entitled *De praxi in aggerum constructione* (1698) – one of twenty other treatises on diverse subjects which he later deposited in the library of the Jesuit library in the college of Ferrara where he passed away at the end of an illustrious teaching career which had started in Bologna and continued in Parma (1675-1681) and in Ferrara (1685-1694).[49] It was perhaps by no coincidence that the courts of Parma and Ferrara, together with that of Mantova were three important Italian principalities north of Rome which repeatedly hired Jesuit mathematicians to serve as military consultants in the seventeenth century.[50]

Following the departure of Macrini, Ferroni's activity in Bologna during the period 1667-1686 seems to have been highly successful. This can be attested by the presence of five tables which were originally included in a manuscript of his teaching notes entitled *L'Arte del fortificare* (1674).[51] After his transfer to Siena in 1686, the Jesuit seminary for nobles in Bologna had continued to flourish. Not only was an important work on '*esercizi cavallereschi*' (outlining the achievement of its *Accademia degli esercizi cavallereschi*) published in July 1717 to commemorate the imperial victory over the Turks marked by the fall of Belgrade,[52] but at about this time the Bologna Jesuits seem to have multiplied their efforts to prepare their students for the Turkish wars, drawing much inspiration from the *Ecole des Cadets-gentilshommes.* This had been set up by Louvois in Paris where

49 ARSI, AHSI 103, a.LII (1983) 89. The treatise of Macrini, who joined the Jesuits on 22-11-1649, is mentioned in ARSI, SMV, V, 266.

50 Gian Paolo Brizzi and Greci Roberto, eds., *Gesuiti e Università in Europa (secoli XVI-XVII).* In *Atti del Convegno di Studi*, Parma, 13-15 dicembre 2001' (Bologna: CLUEB, 2002), 230.

51 D'Ayala, Mariano., *Bibliografia militare italiana, antica e moderna* (Torino: Stamperia Reale, 1854), 130.

52 ARSI, SMV, II, 1677.

mathematics, geography, history, French and German, fencing, design, fortifications, music and dance were taught to the lower and higher nobility.[53] For this purpose, the Jesuit Order hired a military expert from Modena called Francesco Vandelli. This person was requested to give practical instruction (as distinct from theoretical knowledge) in military architecture, focusing on a more effective type of artillery about which he had authored a book about gunpowder entitled *Della polvere da fuoco* (1757).[54]

Another important seminary for nobles responsible for the dissemination of military knowledge in the Emilia Romagna region, this time associated with the Jesuit *Provincia Veneta,*[55] was that of Parma. This institution, dedicated to Santa Caterina, had been set up in 1604 by Duke Ranuccio I Farnese (1569-1622), son of the famous Italian general Alessandro Farnese who had once boasted to the King of Spain that: 'Your Majesty desired me to build a fortified citadel at Maastrich but I thought that a college of Jesuits would be a fortress more effective to protect the inhabitants against the enemies of the altar and the throne. I have therefore built it'.[56] During the 1604-1773 period some 1000 nobles from Germanic countries attended the Jesuit *seminarium nobilium* of Parma, which, for good measure, was also fitted with a grand '*sala de armas*' or armoury. This reflected a remarkable Jesuit influence north of Rome that had been brought about by the concerted effort of four Habsburg noblewomen all having Jesuit confessors – Margherita, daughter of the Emperor Charles V and wife of Duke Ottavio Farnese of Parma; Eleonora, daughter of the Emperor Ferdinand I and wife of Duke Guglielmo I Gonzaga of Mantova; Barbara, daughter of the Emperor Ferdinand I and wife of Duke Alfonso II d'Este of Modena and Giovanna, daughter of the

53 Gian Paolo Brizzi, *La Formazione della classe dirigente nel sei-settecento: i seminaria nobilium centro-settentrionale* (Bologna: Il Mulino, 1976) 246 and fn. 389.

54 *Ibid.* 246 and fn. 388. For Vandelli's work on artillery see D'Ayala, *Bibliografia*, 157.

55 The Jesuit *Provincia Veneta* incorporated five colleges having mathematical faculties at Bologna, Brescia, Ferrara, Mantova and Parma, also including, after 1657, a *domus professa* in Venice where mathematics started being taught in 1744.

56 John Patrick Donnelly S.J., *The Jesuit College at Padua : Growth, Suppression Attempts and Restoration.* In '*ARSI*', AHSI 101, a.LI (1982), 47.

Emperor Ferdinand I and wife of the powerful Grand Duke Francesco I de` Medici of Tuscany.[57] The Jesuit involvement in the Duchy of Parma was dominated by the mathematicians Bettini (1582-1657) and Macrini who had arrived here in 1675 or thereabouts. Mario Bettini was a colourful figure. Besides being the mentor of Guarino Guarini (1624-1683) he was also a close friend of Prince Raimondo Montecuccoli (1609-1680)[58] and was responsible for teaching military architecture in Parma during the period 1624-1630. It is recorded that among the students who attended his classes were the two sons of Duke Ranuccio, Ottavio and Odoardo. According to Silvestri, the Duke was informed in 1612 that Ottavio had already attained full proficiency in 'forming squadrons and ordering an army, well prepared to fire bombards and manage artillery... also very good in geometry and arithmetic, in the fine art of fortification but also in metaphysics and in human and natural philosophy'.[59] Besides being Ottavio's teacher of military mathematics, Bettini also served as military consultant to the courts of Parma (1612-1613), Modena (1617-1618) and again Parma (1626-1627), and as a military architect at Novellara (1618-1619) which was the seat of the novitiate of the Jesuit '*Provincia Veneta*'. He also authored a book about mathematical curiosities (1654) in which '*auctoria militaria*' featured prominently.[60] His ingenious machines of war were mentioned by Montecuccoli, by the famous Jesuit mathematicians Athanasius Kircher and Jacques Ozanam and by that famous Polish master of early modern artillery warfare, Casimir Semenowycz.[61]

It has been estimated that the Jesuit-run seminaries for nobles in Parma, Bologna, Siena and Modena, managed to disseminate in 1660-1773 the most up-to-date knowledge about mathematical applications

57 The role of the Habsburg noblewomen mentioned in the text is explained in Baldini, *Saggi*, 172, fn. 3.

58 He sent Bettini a confidential copy of his fortification works from Hohenneg on 15 July 1652: Brizzi and Greci, *Università in Europa*, 231 and fn.30.

59 Raimondo Silvestri, *Il Principe Infante* (Macerata: Pietro Saluioni, 1620), 252-253. Cited by Denise Aricò in *Politica e Istruzione alla corte di Ranuccio Farnese: i gesuiti Mario Bettini e Jean Verviers*. In Brizzi and Greci, *Universita in Europa*, 213-242.

60 ARSI, SMV, I, 1427-1428. For Bettini's consultancies see Baldini, *Saggi*, 185, 194-195 and 202.

61 Brizzi and Greci, *Università in Europa*, 231.

to military architecture to estimated intakes of some 200-250 students from the Duchy of Savoy and Switzerland, 250-500 from the Duchy of Modena, 500-750 from the Grand Duchy of Tuscany and the Duchy of Parma, 750-1000 from the Duchy of Milan and the Republic of Genoa, 1000-1500 students from the Papal States and the Holy Roman empire and 1500-2000 students from the Republic of Venice.[62] The notes on *De re militari* of the little known Jesuit *mathematicus* Alberto de Albertis that were at one time circulating in Trent as well as a manuscript revealing the private lessons in military architecture that were being given at the Jesuit college of S. Rocco in Parma by the Bergamese Jesuit Carlo Antonio Santi (1663-1729) who had authored a manuscript entitled *Compendio dell'Arte Militare*,[63] would also suggest that some Jesuits were supplementing their classroom teaching by discreet private lessons in military architecture in very much the same way as Galileo had done. To complete the picture of the tremendous influence of the Jesuit seminaries for nobles in the Emilia Romagna region of Italy in the seventeenth century, one must mention the Jesuit seminary in Ravenna where instruction seems to have been focused on '*Esercizi Cavallereschi*'. This subject was then considered to be 'the ornament of a well-born person' and noble parents desired that their children, as future leaders of men, would be taught by the Jesuits how 'to handle the sword, the pike and the flag, to ride well a horse, to dance elegantly in both the French and the Italian manner, to sing, to play different musical instruments, to write and speak different languages and to understand well arithmetic, geometry and all about fortifications!'[64]

62 Brizzi, *Classe diirigente*, 45. See also Luigi Pepe ed., *I gesuiti e i loro libri a Ferrara: frontespizi figurati del Seicento* (Ferrara:Artigiana, 1998).

63 For Albertis see ARSI, AHSI 103, a. LII (1983), 86 and Neill and Dominguez, ed., *Diccionario*, 1246-1248 (*Enseñanza Militar*). For Santi, who joined the Jesuits on 2-12-1680, see ARSI, SMV, VII, 589.

64 Brizzi, *Classe dirigente*, 288 and fn. 402 quoting from a Jesuit document entitled '*Informazione per chi desidera mandar figliuoli nel Collegio di Nobili... in Ravenna*'.